PRELIMINARY PHYSIOLOGY

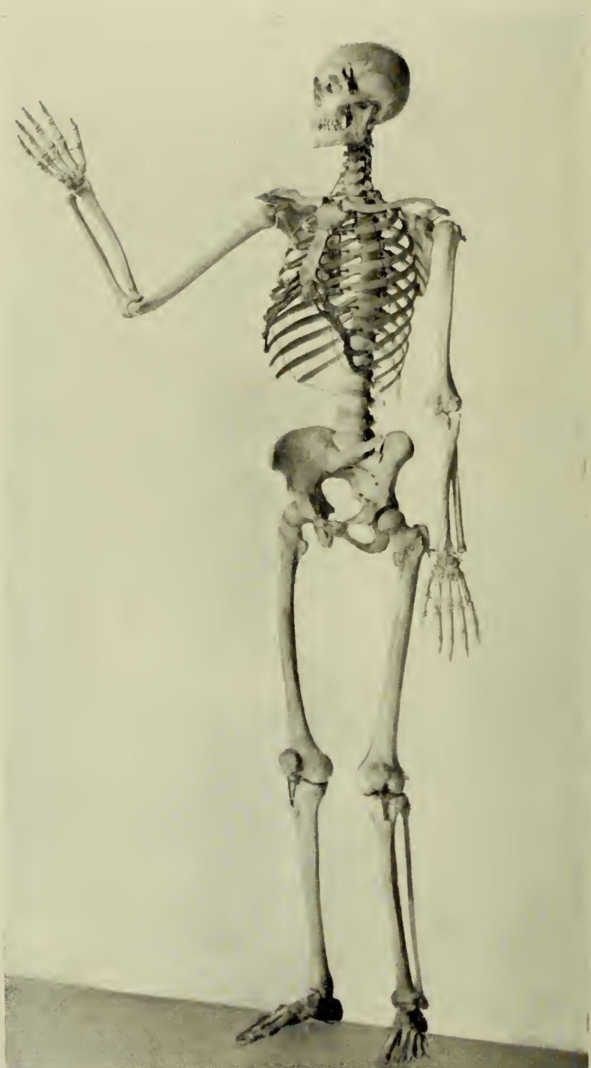

FIG. 1.—SKELETON OF MAN

20 · X · 10 ·   U   34

PRELIMINARY PHYSIOLOGY

BY

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WITH 103 DIAGRAMS AND ILLUSTRATIONS

METHUEN & CO. LTD.

36 ESSEX STREET W.C.

LONDON

2(37348)

First Published in 1910

PREFACE

THE aim of "Preliminary Physiology" is to afford a systematic study of the functions of the organs of the human body. The endeavour has been to present the leading facts of Physiology to the lay reader in an expository style, with free reference to specimens to illustrate the features of structure. Further, the several experiments suggested will enable students to verify many of the facts of Physiology. Frequent repetition occurs in order to emphasize the connexions of structures and functions.

The illustrations for this book have been prepared specially to help the teachings of the text and have not been inserted simply to multiply illustrations. Nearly the whole of the drawings, diagrams, and photo-micrographs have been executed from specimens prepared to illustrate the structures and arrangements of parts concerned. Students, however, are urged to remember that the best illustrations in science teaching are but feeble aids compared with direct observation of the actual objects.

This work is adapted to meet the requirements of the First Stage Examinations of the Board of Education, the Oxford and Cambridge Locals (Senior), College of Pre-

ceptors, and all Preliminary Examinations in Physiology. Students preparing for Second Stage Examinations will find this book distinctly helpful.

The author has followed the method of teaching which has proved highly successful during his many years of experience in teaching Physiology and the allied natural science subjects to students in day and evening classes. These comprise teachers in elementary and secondary schools and colleges, students in training for cookery, physical culture, nurses, and others.

Teachers of Physiology using this book in their classes will find the suggestions offered for practical work valuable. They are strongly recommended to use fresh materials for illustrations in preference to prepared. Teachers will find that microscopical demonstrations of the elementary tissues, the circulation of the blood, and the movements of the living substance—protoplasm—will create real interest and greatly vivify the teaching of Physiology.

Without attempting to teach systematic chemistry, the chemical and physical considerations included in this book will be useful no doubt to many students.

Most of the technical terms employed have been explained in the text, and the terms in the Glossary accordingly have been reduced.

The Appendix contains some considerations better adapted to this position in the book than a place in the text. The Examination Questions have been classified for the convenience of students wishing to test their knowledge of the subject in sections.

My thanks are tendered to those who have assisted me in the preparation of "Preliminary Physiology". Most of

the illustrations have been drawn by a valued student of Physiology, Miss J. Ahlborn, some by Miss B. E. Narramore, Miss A. E. Narramore, my friend James D. Macphail, and my assistant, F. J. Haws, F.C.S. Mr. Haws also has rendered much help in preparing the chapter on "Chemical and Physical Preliminaries".

WM. NARRAMORE.

DEVONIA,
GREAT CROSBY, LANCS,
1910.

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PRELIMINARY PHYSIOLOGY

CHAPTER I

INTRODUCTION

Physiology is a branch of the science of Biology, which science aims at understanding the laws governing the form, structure, and activities of living substance. The **science of Physiology** is concerned in a **study of the functions** or uses of the several structures which comprise the living body.

There is the Physiology of Plants as well as the Physiology of Animals; the latter, however, only concerns us here. Chemistry and Physics enter largely into the study of Physiology. These tell us about the nature and properties of the substances forming the body. Again, Anatomy and Histology, the study of the structures and arrangements of the parts and organs of the body, is necessary to understand rightly the teachings of Physiology.

The animal body is in a condition of continual activity, even during sleep. Parts of the body obviously move, whilst other parts, apparently still, require only the use of suitable instruments to demonstrate movement. To sit, to stand, or walk, to perform the acts of seeing, hearing, or thinking, all involve changes in certain tissues of the body, and it is the province of the science of Physiology to explain these changes.

To study the organs of the body, to observe their form, size, weight, colour, to see how they are built up and to ascertain the relation of one organ to another, apart from their functional

activity, is not Physiology but the science of Anatomy. It is by **observation, experiment,** and **deduction** that we gain a knowledge of the several functions of the body, and the results of this knowledge constitute the **science of Physiology.** All matter, dead as well as living, possesses energy. Energy manifests itself in work, heat, chemical and electrical forces, and Physiology aims to explain how this energy is set free and to account for the conditions calling it into action. Physiology is always demanding to know **how things are done,** and for **what reason they are performed.** These **two questions** must be **emphasized** and **held distinctly apart** in the study of the functions of the living body. The question, **How** a thing is done can only be safely answered when we have a knowledge of the structure of the organ concerned and are able to follow the chemical and physical processes involved. **Why** a function is discharged by a particular organ, the heart or the lungs, must be answered **by realizing the needs of the living organism and its relation to its environment.** Anatomy, the science of structure, can be followed by observation and dissection. **Physiology, the science of function, must be thought out from observation, comparison, and experiment.**

The following chapters aim at giving a preliminary study of the human body and its functions. Much of the teaching should be supplemented by means of the examination and dissection of organs obtained from the lower animals, and also by observing the activities of the living body.

CHAPTER II

PROTOPLASM

Protoplasm, meaning the first substance, **is the name applied to the living, active, growing substance possessed by all organisms.** Its physical appearance as well as some of its attributes can be readily studied by the examination of certain lowly forms of animals and plants. In the water, from a pond or ditch containing decaying plants, are often found microscopic animals known as the Amœba and the Vorticella. A careful study of these organisms will serve as an introduction to this living substance protoplasm. Place a drop of water from such a source on a glass slip, cover it with a thin coverglass and examine it under the microscope. The Amœba, when magnified, say 200 diameters, will be about a quarter to half an inch across, **irregular,** nearly **colourless, semi-fluid,** and **granular looking.** The granular portion is inside a pale, thin boundary line. In the midst of the granular portion is an **oval,** or **rounded,** and a **firmer looking body,** named the **nucleus.** The body substance is **alive;** it thrusts out portions and withdraws others, being susceptible to bodies coming in contact with it. The substance **shows motion** of **parts**; it also exhibits slow movement from place to place or **locomotion.** By pushing out and withdrawing portions of the body substance it performs the action of arms and legs. This lowly organism **takes in particles of food** and **digests them.** The body is **nourished, it grows,** and sooner or later **divides into two,** and in this way **multiplies its kind.**

Next observe the Vorticella or Bell-animal in the same water, and note how the form of this microscopic organism gives rise to its name. It is not irregular like the Amœba, but has the **appearance of a small bell on a long handle.** It is **semi-**

fluid and **granular looking**, and in the midst of the granular portion there is a **long, curved nucleus.** The bell shape of the body is maintained by a delicate, skin-like structure. **Around** the **rim** of the **bell** and **elsewhere** are to be seen fringes of living substance like fine, colourless hairs, named **cilia,** from their fancied resemblance to eyelashes. The bell-animal is very **susceptible to any vibration** of the stage of the microscope, or when any minute body touches it. It will then **contract** and **close** in the **bell,** and the stem will **curl** like a **spiral thread.** Its appearance is completely altered, but it quickly recovers and resumes the bell-like form.

FIG. 2.—Amœba (highly magnified).
a, Nucleus ; *b*, Contractile vesicle.

Students of science have gained much information from observations made on these two organisms. The **living substance is semi-fluid** and **contains few** or **many granules,** it **encloses** a **firmer body,** the **nucleus.** The **living substance** or **protoplasm** manifests **movement,** by **extension** and **retraction** of portions of its body and also by the **lashing** of **fine processes** of the **protoplasm, cilia.** It **takes in substances** by way of **food,** in virtue of which **it grows** and **multiplies.** These and other things we know about the **physical** and **physiological** side of the living substance.

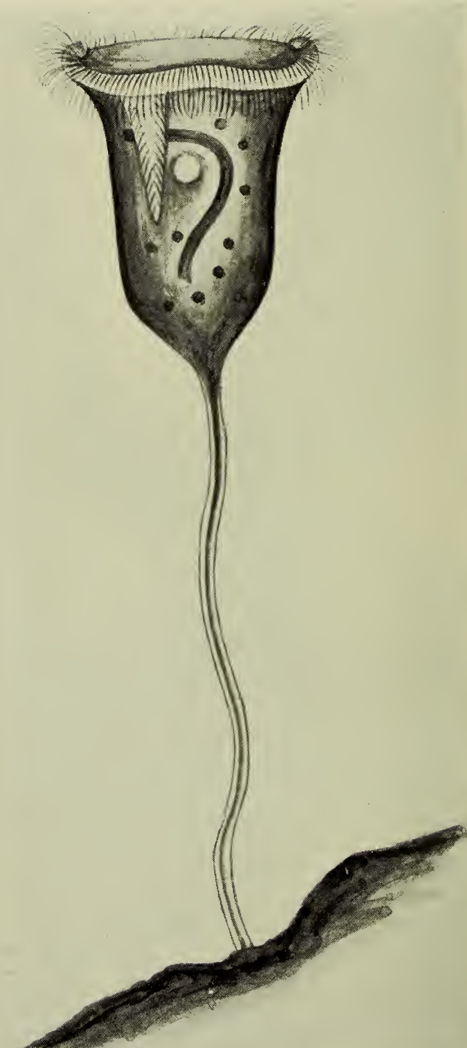


FIG. 3.—VORTICELLA. SEMI-DIAGRAMMATIC

CHAPTER III

CELLS AND TISSUES

An animal such as the Amœba or the Vorticella may be defined as a microscopic body of protoplasm enclosing a smaller body, the nucleus. Each animal is a single cell or a unicellular organism. Every animal begins life as a cell, that is, as a microscopic mass of protoplasm enclosing a nucleus. This single cell lives, grows, and divides to form a number of cells. These cells **change, alter,** and **differentiate** into **structures** named **tissues,** and the complex bodies of higher animals are thus built up.

CELLS. In the animal body are found **many kinds of cells,** and it is interesting to note that there are cells which resemble the Amœba, for instance, the colourless cells of the blood and lymph. These cells move just like the Amœba, and the **movement of these cells** has been termed **amœboid.** There are also **cells with cilia** found in the breathing tubes and elsewhere in the body, and these ciliated cells may be compared to the bell-animal.

Cells play an all-important part in the various functions of the body, and their study requires the aid of a microscope.

TISSUES. To become acquainted with the **structures** or **tissues** of the body, an examination and dissection of a piece of fresh meat is helpful. A thin, transparent membrane, smooth and moist, covers the flesh. It also passes into the midst of the flesh, and in case of fatty tissue a similar membrane binds the

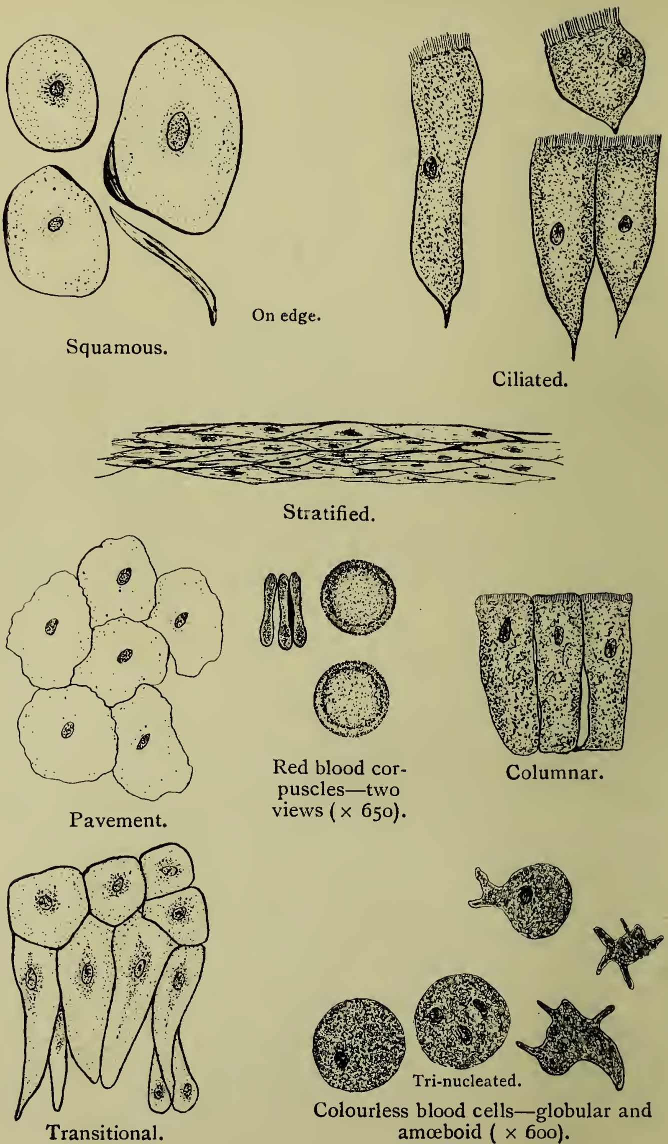
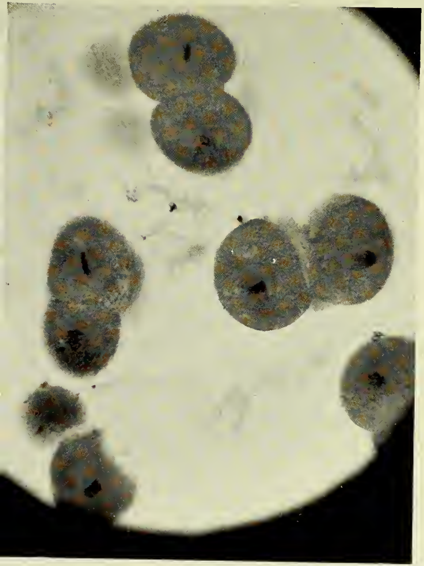


FIG. 4.—Epithelial cells and blood cells.



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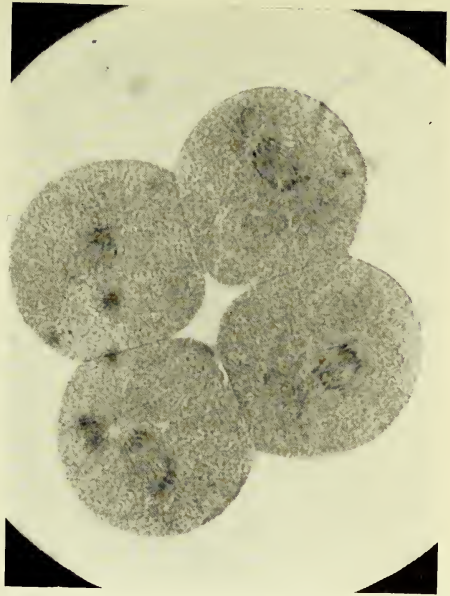
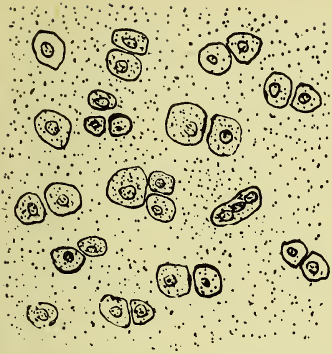


B

C

FIG. 5.—DIVISION OF GERM CELLS. PHOTOMICROGRAPHS
A. DIVISION INTO TWO. × 300
B. ,, ,, FOUR. × 550
C. NUCLEAR DIVISION. × 625 (W.T.H)



Hyaline cartilage.

White fibrous.

Adipose.

Striated muscle fibres.

Elastic.

Fig. 6.—Tissues.

mass together. Examined by the aid of the microscope the tissue is seen to be made up of **branching cells** and **fine fibres.** The fibres are in bundles which cross and recross in several directions. The **tissue** is known as **Connective tissue,** and it serves to support, connect, and bind other structures together. Connective tissue sometimes has **elastic fibres** in its web and it then becomes more or less elastic. **Elastic tissue** is present in the skin, the lungs, and in other parts of the body.

TENDON is a compact form of connective tissue. **Tendons,** as strong bands and cords, **serve** to **fasten muscles** to **bones. Ligaments** of tough, fibrous, connective tissue are found **binding bones together.**

Cartilage, also a kind of connective tissue, is found at the ends of bones which form perfect joints. **Cartilage,** as well as a whitish, flexible structure, connects the ribs to the breast-bone and joins the bones of the vertebral column. Microscopically, cartilage is made up of **cells** and **fibres.** In the course of the development of the body, much of the cartilage first formed is changed into a dense, hard form of connective tissue and becomes bone. **Bone is a tissue composed of cells, fibres, and much mineral substance.** Covering the bones is the flesh, or **Muscular tissue,** and accompanying the muscular structures are fine, whitish-looking fibres belonging to the **Nervous tissue.** There is present, also, more or less of fatty or **Adipose tissue.** This is composed of minute bladders or cells containing **fat** or **oily substance.** Blood vessels present belong to the **Vascular tissue.**

From these considerations, we gather that cells may mass together and form **cellular tissue ;** or cells and fibres associated together go to form **connective tissues** and serve several functions. Further, by the **alteration** and **differentiation** of **cells, muscular, nervous,** and **vascular tissues** are **formed.**

Tissues are **structures** which are found making up parts of the body known as organs. **Organs** have distinct uses or

functions to perform. The heart and blood vessels are the organs of circulation ; the lungs are the organs of respiration. **Physiology** comprises the study of the **functions** of the **organs** of the **body,** and a knowledge of the **structures** or **tissues** is **essential** to the **proper understanding** of the **functions.**

CHAPTER IV

CHEMICAL AND PHYSICAL PRELIMINARIES

Students of Physiology will find it necessary to have definite meanings attached to the use of certain terms often occurring in the explanation of the functions of the body. To have an elementary knowledge of certain physical and chemical actions constantly taking place in the tissues and organs of the body, it is essential that this chapter be devoted to a brief explanation of such terms and actions.

MATTER is used to mean "**anything perceptible to the senses; that of which the whole sensible universe is composed**". Thus employed it includes, and is restricted to, everything which possesses **weight** and **occupies space**. Since all substances existing as **solid, liquid**, or **gas** occupy a certain **space, this amount of space is termed its volume.**

Every particle of matter will attract every other particle of matter in whatever state it exists; this attraction is named the **Law of Gravitation. One** result of this attraction is the **downward pressure** a substance exerts on whatever may support or prevent it from falling to the earth; this **pressure** is termed the **weight** of the **matter.**

All matter, dead as well as living, possesses **energy** or **power to do work. Energy,** so far as is known, may exist apart from matter, but matter is not known apart from energy. The sciences of **Physics** and **Chemistry** have to deal with certain of the properties of matter and of energy and of the changes which they undergo.

We are aware that the various materials making up the earth on which we live differ considerably one from another, and for convenience may be classified according to their different chemical and physical properties. The chemist recognizes all matter as made up of chemical **elements**, of which there are upwards of seventy now known. These are known as elementary bodies because they cannot be simplified. Some thirteen of these elements are commonly found in the body, viz.: hydrogen, oxygen, nitrogen, carbon, sulphur, phosphorus, sodium, potassium, chlorine, calcium, magnesium, iron, and fluorine. These do not usually exist as elements in the body, but unite with one another to form compounds. A recognition of the chief properties of these elements is now essential.

HYDROGEN is a colourless, odourless gas; the lightest substance known. It is only very slightly soluble in water, and therefore may be collected over water or by upward displacement. Hydrogen combines readily with oxygen, and when mixed with half its volume of oxygen, it may be exploded, the sole product being water.

OXYGEN is a colourless gas with neither taste nor smell, and not very soluble in water. It unites with most of the elements directly, forming oxides; this union is often accompanied with an evolution of light and **always** with that of **heat.** On the other hand, substances may be oxidized without evolution of light, but never without evolution of heat. **Animals,** in breathing air, convey oxygen into their blood, where the compounds of **carbon** and **hydrogen** are oxidized and **animal heat is thereby produced.** Similarly, the small amount of dissolved oxygen in water is sufficient to provide fishes, frogs, and other forms of life with means of sustaining respiration. The presence of a certain percentage (21 per cent) of oxygen in the atmosphere, allows animal respiration to take place with the right rapidity of oxidation; in the absence of oxygen, animals soon die, whereas if pure oxygen be breathed, too rapid oxidation takes place and a state of fever results.

AIR is a mixture of oxygen and nitrogen, with traces of carbon dioxide, water vapour, ammonia, and organic matters. When analysed it is found to consist of (approximately)—

Oxygen, 23 per cent by weight; 21 per cent by volume.
Nitrogen, 77 " " 79 " "

NITROGEN is a colourless, odourless, tasteless gas, nearly insoluble in water. It constitutes about four-fifths of the volume as well as of the weight of the air. If breathed apart from oxygen it does not sustain life. Nitrogen serves as a **dilutant** of the oxygen of the air.

CARBON exists in several forms of varying purity in substances as diamond, graphite, charcoal, and others. Carbon burns when heated strongly in oxygen, forming carbon dioxide (CO_2), and under other conditions it forms carbon monoxide (CO). Carbon enters into the composition of all animal and vegetable tissues, and as the compounds of carbon with hydrogen, and their derivatives are so very numerous, they have been separated into an important branch of Chemistry known as "Organic Chemistry". The presence of carbon in these "**organic**" substances may usually be shown by burning. If further heated, the charred mass gives off CO_2 gas, which is the result of the burning of the carbon present. Its evidence in expired air is shown by the precipitation of lime water forming carbonate of lime.

SULPHUR is the well-known yellow brittle solid, insoluble in water. It is found in the body combined with other elements such as carbon, hydrogen, and oxygen forming proteid substances. Sulphur is also evident in decomposition products in the alimentary canal.

PHOSPHORUS, like sulphur, similarly occurs in many of the complex compounds found in the body. It is a very important constituent of brain and nervous tissue.

SODIUM and POTASSIUM are two important elements which only occur in nature as compounds, such as sodium chloride ($NaCl$) or common salt and potassium chloride (KCl).

Both elements unite directly with water forming hydroxides or hydrates, known respectively as sodium hydrate (NaOH) and potassium hydrate (KOH), or caustic soda and caustic potash. The solution is said to be "alkaline"; the name alkali is often applied to these hydroxides, and the metals are called the metals of the alkalies.

CHLORINE at the ordinary temperature is a yellowish green gas with a disagreeable smell; it is sparingly soluble in water, to which it imparts its smell and colour. It combines directly with most other elements, especially with hydrogen, forming HCl. It exists in the body as chloride, sodium chloride, NaCl; hydrogen chloride or hydrochloric acid, HCl.

CALCIUM is a metal and is widely distributed in nature as limestone. It exists in the composition of bone as phosphate of lime $Ca_3(PO_4)_2$ and carbonate of lime ($CaCO_3$). Calcium or lime salts also occur in minute quantity in the blood and in certain excretory products.

MAGNESIUM is a metal, and in combination is widely found in nature. It exists in small quantities in the body.

IRON, although found in comparatively small quantities in the body, is a very important constituent of the red colouring matter of the blood.

In order to avoid writing the names of the chemical elements at full length, a kind of chemical shorthand has been devised. These **symbols**, as they are termed, are frequently the first letter of the name; sometimes two letters. Symbols have still a further meaning; they represent **definite quantities** of the elements represented.

Many of the elements when heated suffer change. Other substances suffer change, and when their temperature is sufficiently raised they **decompose** into two or more different kinds of matter, as **elements** and **compounds**. A compound when heated does not always decompose into its constituent elements, but often into simpler compounds, which may be in turn reduced into the elements of which they are composed.

ELEMENTS not only combine with one another, but with compounds, and further, compounds may combine with one another. **Water**, which is formed by the union of the two **gases** hydrogen and oxygen—both of which are elements—is a compound which is **liquid** at the ordinary temperature. **Common salt** consists of the **solid metal sodium** and the **gaseous element chlorine**, which combine and form the **white crystalline solid.**

CARBOHYDRATES, such as sugar and starch, consist of carbon with the elements of water, H and O, while the **Proteids** found in the body are compounds of C, H, O, N, S, and P, and have been formed by the union of **other compounds** and **their elements.** As a rule, the compound formed does not resemble in physical properties the elements of which it is composed.

A list of the commoner elements and their symbols are given in the APPENDIX, and when the student has become familiar with them, they may be used to denote compounds by placing the symbols together. If two symbols are placed side by side, it indicates that the two elements are chemically combined to form a compound, e.g., CaO represents calcium oxide, lime; CO_2 represents carbon *di*oxide, and so on. These double symbols are known as **formulæ** (*sing.*, **formula**), and by means of these we can express nearly all chemical reactions in **equations**:—

$$\underset{\text{Hydrochloric Acid}}{HCl} + \underset{\text{Caustic Soda}}{NaOH} = \underset{\text{Sodium Chloride}}{NaCl} + \underset{\text{Water}}{HOH} \text{ (or } H_2O)$$

From the above **equation** it will be seen that a chemical **formula not only expresses** the **nature** of the elements that compose the compound, but also the **relative proportions by weight** in which the elements are present. Thus the **symbol** of an element represents **one atom** and the **formula** of a compound represents **one molecule.** By using the table of atomic

weights it is now possible to **calculate** the weights of materials used in **chemical reactions**, for example: If, in the above equation, we obtained 10 grms. of common salt, how much hydrochloric acid (by weight) would have to be used? Then by the above equation and table of atomic weights :—

$$\underset{HCl}{1 + 35.5} + \underset{NaOH}{23 + 16 + 1} = \underset{NaCl}{23 + 35.5} + \underset{HOH}{1 + 16 + 1} \text{ (or, } 2 + 16\text{)}$$

$$= 36.5 \quad + \quad 40 \quad = \quad 58.5 \quad + \quad 18$$

or,

36·5 parts (grammes, ounces, or tons) of hydrochloric acid and 40 parts of caustic soda produce 58·5 parts of common salt and 18 parts of water. Finally, if 58·5 grms. of salt are produced from 36·5 grms. of HCl, what amount of HCl will produce 10 grms.?

$$= 58.5 : 10 :: 36.5 : x \; (= 6.23)$$

In the **animal body** are found a series of **chemical compounds** grouped together forming what are known as **proximate principles.**

These are best classified as follows :—

Inorganic
- **Water** (consisting of the elements H and O).
- **Mineral salts,** namely, calcium phosphate (Ca, P, and O); calcium carbonate (Ca, C, and O); sodium carbonate (Na, C, and O); sodium chloride (Na and Cl); sodium phosphate (Na, P, and O); potassium chloride (K and Cl); potassium-hydrogen-phosphate (K, H, P, and O); iron (Fe); magnesium (Mg).

Organic
- **Proteids** (existing as albumen, fibrin, globulin, etc., and consisting of the elements C, H, O, N, S, and P).
- **Carbohydrates** (e.g., glycogen or animal starch, C, H, O).
- **Fats** (C, H, and O).

CHAPTER V

THE BODY: ITS DIVISIONS AND GENERAL ARRANGEMENT OF PARTS

The divisions of the human body are head, neck, trunk, and upper and lower limbs. A vertical section of the body from top to bottom shows it to have **similar parts laterally.** The body, therefore, is referred to as being **bilaterally symmetrical.** Such a section further demonstrates that the **back** or **dorsal** part, besides being formed of a series of small bones one on top of another, the **vertebral column,** encloses a **vertebral canal.** This canal **opens widely** at the top and is bounded by the large skull bones. Thus the back or dorsal part of the body has a continuous cavity, large above and enclosing the brain; narrow below enclosing the spinal marrow.

The **front** or **ventral** part of the body reveals a small upper cavity, the mouth, and below this a large ventral division. The latter is divided by a horizontal partition, the midriff or diaphragm, into an **upper** portion, the **chest** or **thorax,** and a **lower division,** the **abdomen.** The ventral cavities contain a number of organs which are engaged in carrying on the work of the body. The functions of these organs are controlled by the **central nervous system,** the brain and spinal cord, which is lodged in the dorsal region of the trunk, and by the **sympathetic nervous system,** which forms a double chain in front of the vertebræ from the neck region to the bottom of the abdominal cavity.

On the **ventral** or front side of the body is a **long tube,** the

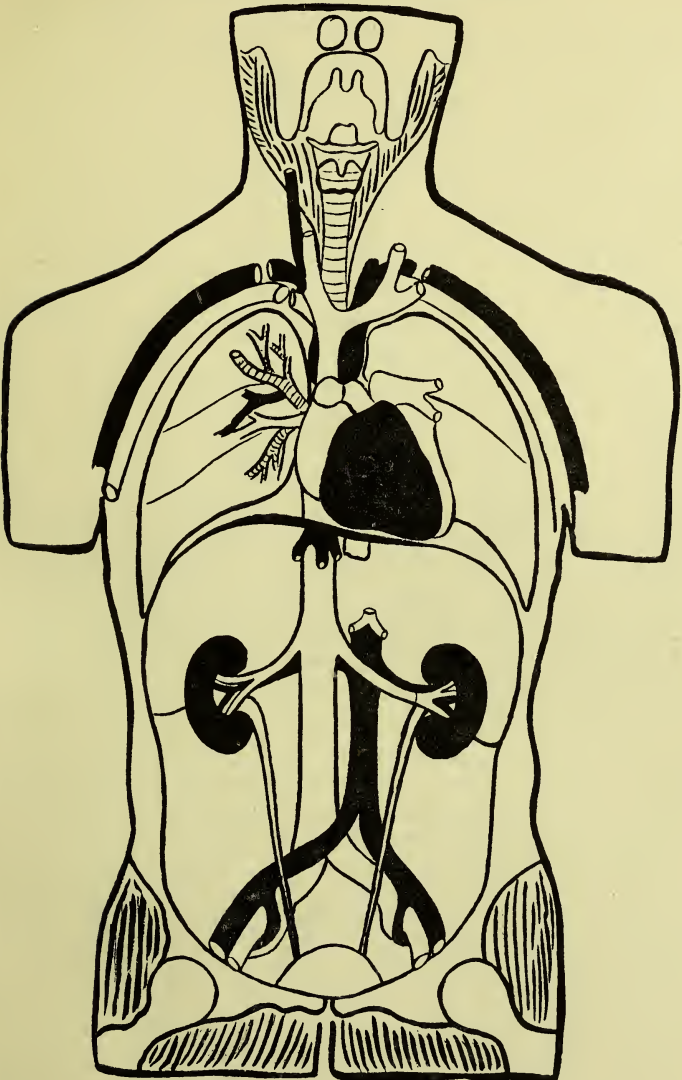


FIG. 7.—Body cavities—organs in position.

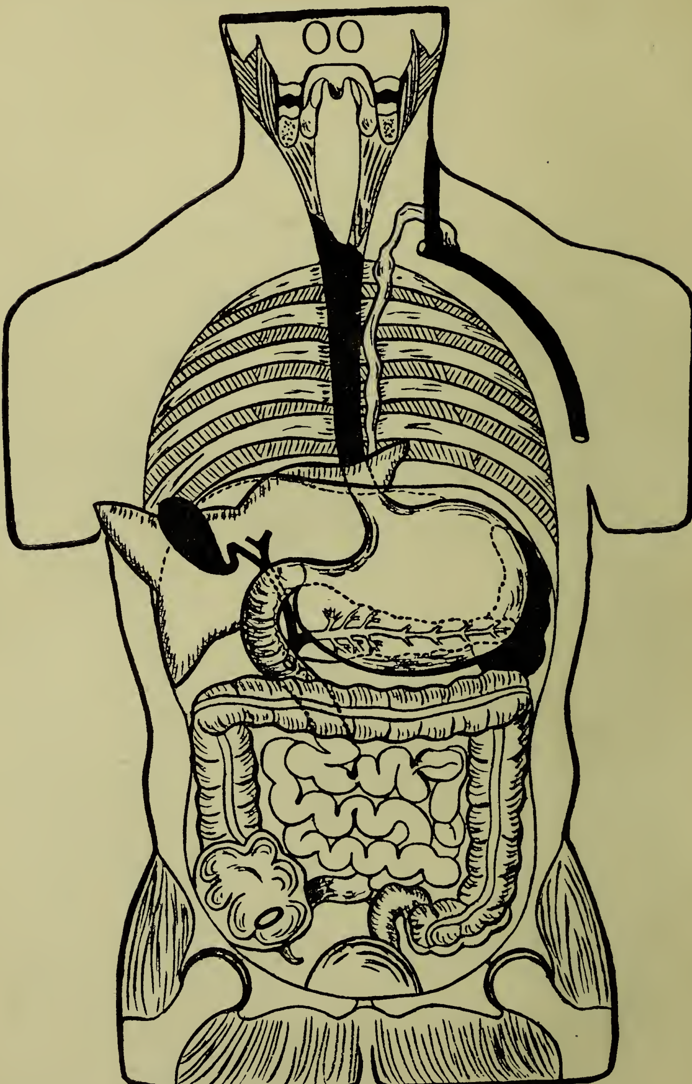


Fig. 8.—Body cavities—organs in position.

alimentary canal, in which the digestive processes are carried on. This tube begins with the mouth entrance which leads to the **pharynx** and **gullet,** and at the lower end the gullet opens out into a wide, bag-like portion, the **stomach.** The stomach is lodged in the abdomen below the diaphragm ; it is continued as a **long, tubular, intestinal canal,** which occupies a large space in the abdomen. The intestinal canal is coiled upon itself several times and at its lower end terminates in the anal outlet. Associated with the alimentary canal are glands which open into it by means of tubes or ducts. At its beginning the **salivary glands** open into the mouth. In the abdomen the **liver** and the **pancreas** have ducts leading into the first division of the intestinal portion of the alimentary canal. The liver is a large, dark red organ immediately below the diaphragm, and the pancreas is a loose, lobulated structure situated below the stomach.

From the foregoing it will be seen that nearly the whole of the structures concerned in digestion are situated in the abdominal portion of the ventral cavity. The **abdomen** is **bounded above** by **an arch formed by the diaphragm,** at the **bottom** by the **hip-bones,** these forming a kind of basin, the **pelvis,** whilst the **back** of the abdomen is bounded by a portion of the **back-bone,** and the **sides** and **front** by **muscles** and **skin.**

In the abdominal cavity, in addition to the organs of digestion, are found the **two kidneys,** situated against the back and right and left of the vertebral column. By ducts, the kidneys are connected with a pear-shaped bag, the **bladder,** which is placed in the pelvis at the bottom of the abdomen. Another organ, the **spleen,** is found near the stomach on the left side of the abdomen. The **whole** of the **interior** of the **abdominal cavity** is **lined** by a **smooth, thin membrane,** the **peritoneum.** This membrane, besides lining the cavity, is reflected over all the organs contained in the abdomen. A smooth and moist outer surface to all parts is thus provided.

The **upper division** of the **ventral** cavity is the **thorax.** It

is **bounded** by the **back-bone,** the **ribs,** and **breast-bone,** and the **floor** is formed of the **convex upper surface** of the **diaphragm.** Muscles and skin cover the bony walls. The thorax contains the important **organs** of **circulation** and **respiration ;** the heart and the larger blood vessels occupy nearly a central position, whilst the two lungs fill in the remainder of the cavity of the thorax. The **thorax,** like the abdomen, is **lined** by a **layer** of **smooth, moist membrane,** which is reflected over the lungs and heart and known as the **pleura** and **pericardium** respectively.

The **appendages** or **limbs,** the arms and legs, are alike in having similar parts : the upper and the lower divisions, and the hand or foot. The upper limbs are variously modified in vertebrate animals to serve diverse purposes ; in man they are essentially **organs** of **prehension.** On the other hand, the lower limbs are **adapted** to **support** and **locomotion.** The appendages of the body are practically solid structures compared with the trunk. They have long bones in the midst of masses of muscles, and these enclosed by fat and skin. Whereas in the trunk the bones form a framework, covered with muscles and skin, enclosing cavities which contain various organs.

Man viewed as an erect animal. We note that the skull is perfectly balanced at the top of a series of bones, forming the vertebral column. The base of this column is embraced by a strong, broad girdle of bones, through the medium of which the weight of the body is transferred to the lower limbs. The upper limbs are attached to the trunk in a loose manner, allowing great freedom of the arms for the purposes of prehension.

The broad features of the parts of the body and their arrangement here sketched will serve as an introduction to the detailed descriptions of the subsequent chapters.

FIG. 9.—SIDE VIEW OF THORAX AND SKULL

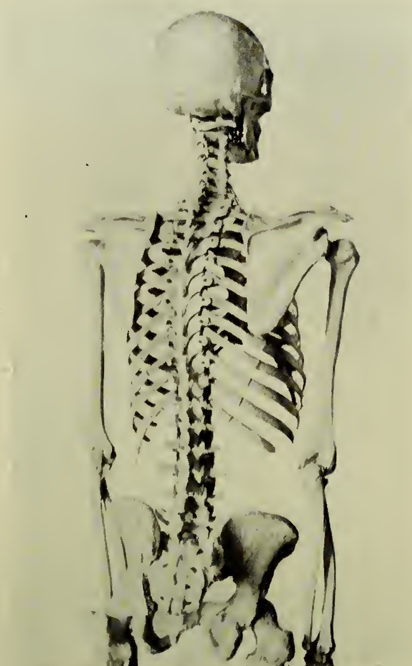


FIG. 10.—BACK VIEW OF SKELETON

CHAPTER VI

THE SKELETON

The **skeleton** of a mammal is **internal**, like all members of the large division of animals known as the vertebrate animals—and man belonging to this division has an **internal bony framework.** This is covered by masses of red flesh, the muscles, and these are further clothed with skin. The skin again has a partial covering of hairs, and the ends of the fingers and toes are modestly protected with horny nails.

The **skeletons** of all **mammals, animals which suckle their young**, are built on the same plan. A brief examination of the skeletons of a number of animals in a museum will readily satisfy the mind on this important fact. Moreover, it will be seen that the bony framework is similarly divided throughout. The head, neck and trunk, a number of ribs and two pairs of limbs. Each limb, arm or leg, has three divisions. The limbs are adapted for support, prehension, and locomotion. A skeleton prepared and free from all other structures is seen to be composed of a number of dry bones, of different forms and variously joined together. For convenience of description consider the **skull, trunk**, and **limbs.**

The **skull-bones** include **two divisions** :—

(*a*) The **cranial** division of **eight bones** enclosing the brain.

(*b*) The **facial** division of **fourteen bones.**

The bones enclosing the brain are firmly held together by irregular, toothed edges, dovetailing one into another, or the thin

edges of one bone lapping over that of another. These unions are named **sutures**, meaning a stitching.

The **eight cranial bones** are:—

4 single—1 Frontal, 1 Occipital, 1 Ethmoid, 1 Sphenoid.

4 in two pairs—2 Temporal, 2 Parietal.

The **fourteen bones of the face** (facial) are:—

2 single—1 Inferior Maxillary, 1 Vomer.

12 in six pairs—2 Superior Maxillary, 2 Palate, 2 Malar, 2 Nasal, 2 Lachrymal, 2 Inferior Turbinated.

Reference should be made to the positions of these bones by an examination of the human skull. The following brief description will indicate the positions.

The **Frontal** bone forms the forehead and the upper boundaries of the eye-sockets. The **Parietals** form the side walls and crown of the skull. They are joined along the middle line above. The **Occipital** occupies the back and base of the cranium. It has a large opening bounded by two condyles. The condyles articulate with the first vertebra. The large opening allows of the connexion of the spinal cord with the brain. The **Temporal** bones are at the sides of the skull. They contain the organs of hearing in the deep portions. The **Ethmoid** bone is situated between the brain and nasal cavities. The perforated portion, or cribriform plate, allows of the passage of the nerves of smell. The **Sphenoid** is a very irregular, wedge-shaped bone, locking together the bones of the face and cranium. It forms a portion of the base and sides of the skull.

The **eight cranial bones** are mainly broad and concave, irregular in outline, and firmly joined together to form a strong case for the brain. Many openings for the passage of nerves, and lines of impression of the blood vessels, may be noticed on the inside of the bony case.

The **facial bones**, fourteen in number, of which the two **Superior Maxillary** bones form a considerable portion of the face. They join along the middle line of the face to form the

upper jaw, which contains sockets for the lodgment of the upper teeth.

The **Inferior Maxilla** or lower jaw has a roughly horseshoe-shaped body in which are lodged the lower teeth. From the extreme ends of the body, the vertical portions or ascending rami, go to form articulations with the temporal bone. The articulation of the lower jaw permits of an up-and-down or

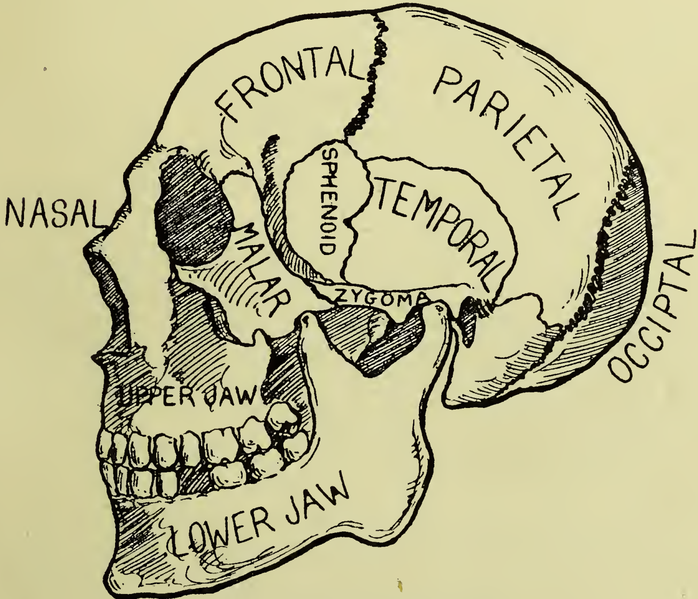


FIG. 11.—The skull—side view.

vertical movement, and a side-to-side or lateral movement, employed in mastication.

Two Nasal bones form the bridge of the nose; and two **Lachrymal bones** occupy the inner corners of the eye-sockets. **Two malar** or cheek-bones form the lower front portions of the eye-orbits. **Two Palate bones** form the bony roof of the mouth and the floor of the nasal cavities. The **Vomer** is a

vertical plate of bone between the two nasal cavities. In the lower part of the nasal cavities are two twisted, scroll-like bones, the **Turbinated.** Above the turbinated bones are scroll-like arrangements of bone, named middle and superior turbinated, whilst the lower bony structures are named inferior turbinated bones. These complex structures have important uses in the function of breathing.

The bones of the face are characterized by irregularity of shapes. They unite by overlapping edges and projections, named sutures.

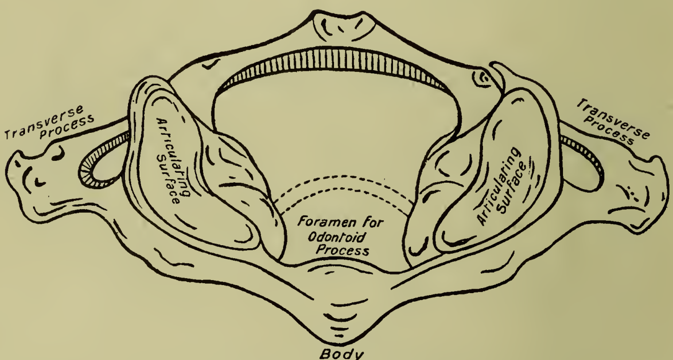


FIG. 12.—Atlas vertebra.

THE VERTEBRAL COLUMN. In the human skeleton the skull is balanced on the **spine** or **vertebral column.** The column is made up of a series of bones or **vertebræ joined together** by **pads of flexible cartilage.** It is not straight and rigid, but presents graceful curves, and by the method of union of the bones the column has a certain amount of flexibility. In early life the number of vertebræ is thirty-three ; in adult life the number is reduced to twenty-six, due to the union of several vertebræ at the base of the column.

The vertebræ are divided as follows :—

7 **Cervical** or Neck.

12 **Thoracic** or Dorsal, to which the twelve pairs of ribs are attached.

5 **Lumbar** or Loin vertebræ.

5 **Sacral,** which become firmly united to form a wedge-shaped bone between the pelvic bones; named the **Sacrum.**

4 **Coccygeal** or tail-bones; these join to form the **Coccyx.**

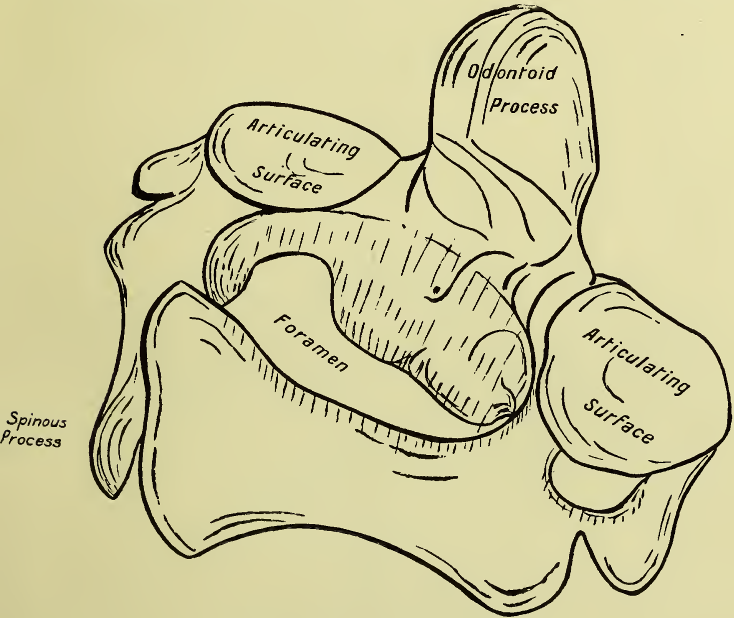


FIG. 13.—Axis vertebra.

In the several parts of the column the vertebræ have slightly varied characters by which it is possible to distinguish them one from another.

The following parts may be traced in them all:—

(*a*) A **body** or **centrum.**

(*b*) An **arch** or **ring** of bone behind the centrum.

(*c*) A **spinous process,** the most posterior portion of the ring.

(*d*) Two **lateral** or **transverse processes.**

(*e*) Four **articulating surfaces,** two for the vertebra next above, and two for the one below.

(*f*) **Two lateral openings** for the exit of the spinal nerves.

The vertebræ belonging to the several parts of the column are distinguished by certain variations of the typical parts they show, namely, the **size** of the **body,** the **length** and **direction** both of the **spinous** and **transverse processes,** and the **position** of the **articulating surfaces.**

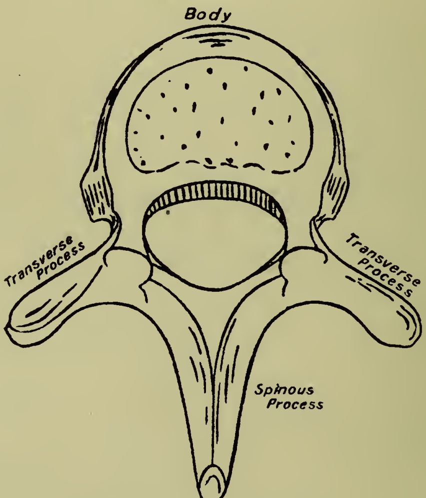


Fig. 14.—Dorsal vertebra.

The **Sacrum** consists of **five fused vertebræ,** and the typical parts are somewhat indistinct. The firm bony union forms a solid base to the vertebral column and also provides a rigid union with the hip-bones. The lateral openings for the spinal nerves are large in the sacrum. The typical features of a vertebra are lost in the coccyx ; this part has become rudimentary.

Except the **first** and **second vertebræ,** the cervical, dorsal, and lumbar vertebræ have their **bodies joined** one to another

by **pads** of tough, fibrous gristle or cartilage, and they are further bound together by bands of tough fibres of connective tissue forming **ligaments.** The articulating surfaces are smooth and well lubricated. These conditions allow of a certain amount of bending of the column, and the pads of cartilage are slightly compressible. The arches or rings of the vertebræ being placed

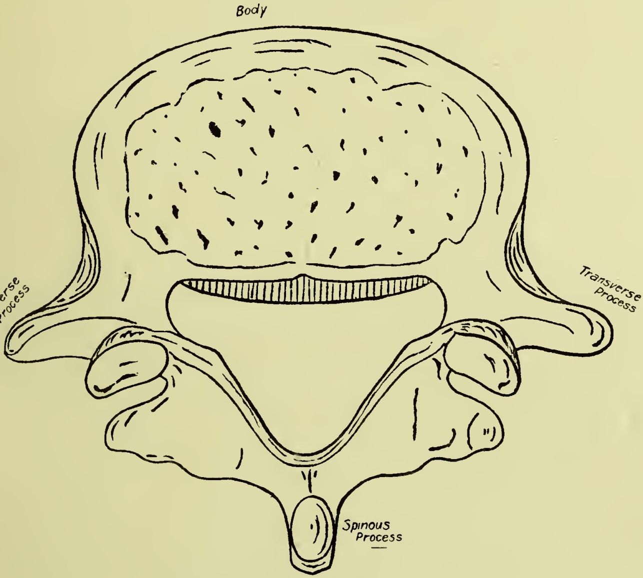


FIG. 15.—Lumbar vertebra.

one over the other form the vertebral canal for the lodgment of the spinal cord.

Two vertebræ, the **first** or **Atlas,** and the **second** or **Axis,** demand special attention. Their form has been much modified as compared with the others. The **atlas** is a **ring** of **bone**—the body is greatly reduced. Just inside the front border is a smooth, articulating surface, and also on the upper and under sides are broad surfaces for articulation. The **axis** has its body

modified and elongated into a **tooth-like** or **odontoid peg.** In front of this peg is an articulating surface corresponding to the one inside the ring of the atlas. The axis has also large, smooth surfaces on its upper side to articulate with those of the under side of the atlas. These vertebræ allow of the nodding of the head and the side-to-side movement of the head. To nod the head, the **condyles** at the base of the **occipital** bone **articulate** upon the **upper surface** of the **atlas.** To turn the head from right to left or left to right, the **atlas moves part way round** the **peg** of the **axis.** It is kept from moving too far by check ligaments. A transverse ligament also passes behind the odontoid peg of the axis to keep it in position.

CHAPTER VII

THE SKELETON (*Continued*)

The shoulder and pelvic girdles and limbs. The **shoulder girdle** includes the two blade-bones or **Scapulæ,** and the two collar-bones or **Clavicles.** The latter join the top of the sternum and complete the girdle in front, but at the back the blade-bones do not meet. The **pelvic girdle** is formed by the **hip-bones** at the sides and in front, and at the back the **hip-bones become firmly united** to the **sacrum,** thus completing the **ring** or **girdle** for the attachment of the lower limbs.

The **Scapula** is triangular in shape, with a strong spinous ridge across the outer side, which projects beyond the body of the bone as the **acromion process.** Just below this process on the inner side is another, the **crocoid process.** These two projections help to deepen the **socket** or **glenoid cavity** for the head of the upper arm-bone. Each scapula is held in a mass of muscles at the back of the shoulder, and this loose fixing of the blade-bones allows of the freedom of the arms in backward and forward movements.

The **Clavicle,** collar or key-bone, has a double curve, and is about 4 in. in length. It crosses above the first rib in front from near the end of the acromion process of the scapula to the upper end of the sternum.

The bones of the upper and lower limbs compared :—

Upper arm, 1 bone, Humerus.	Upper leg or thigh, 1 bone, Femur.
	Knee-cap—Patella—1 bone.

Lower arm, 2 bones, Ulna and Radius.	Lower leg, 2 bones, Tibia and Fibula.
Wrist, 8 bones, Carpals.	Ankle and heel, 7 bones, Tarsals.
Hand, 5 bones, Metacarpals.	Foot, 5 bones, Metatarsals.
Fingers, 14 bones, Phalanges, 3 in each finger, 2 in thumb.	Toes, 14 bones, Phalanges, 3 in 4 toes, 2 in big toe.
Total number of bones, 30.	Total number of bones, 30.

The **Humerus** and the **Femur** are long and somewhat cylindrical-shaped bones. The parts of each are, the **head,** the **shaft,** and the **articulating condyles.** In contrast, the femur is longer and stronger than the humerus, and between the head and shaft it has a well-marked neck.

The **Ulna** at its upper end is large, and it has a deep groove which articulates with the lower end of the humerus to form the elbow-joint. The projecting end of the ulna, the elbow, fits into a depression at the back of the lower end of the humerus, when the lower arm is in extension. The **Radius** is on the outer side of the ulna and parallel with it. The radius is large at the lower end, and it articulates with the wrist-bones and carries the hand. When the palm of the hand is turned down, **pronation,** the radius crosses the ulna. When the palm is turned upwards, **supination,** the radius is parallel with the ulna.

The **Tibia** and **Fibula** of the lower leg are long bones, but the tibia is the stronger, and it articulates by its upper end with the lower end of the femur to form the knee-joint. The fibula, which lies to the outer side of the tibia, takes no part in the formation of the knee-joint. The **Patella** or knee-pan, small, flattish bone, protects the front of the knee-joint.

At its lower end the tibia articulates with the **Astragalus,** the highest of the tarsal bones. Below and behind the astragalus is a single bone, the **Calcaneum,** which forms the heel. The remaining five tarsal bones, together with the metatarsals, complete the arch of the foot; continued in front

of the latter are the phalanges of the toes. The wrist or carpal bones are much smaller than the tarsal bones. The eight

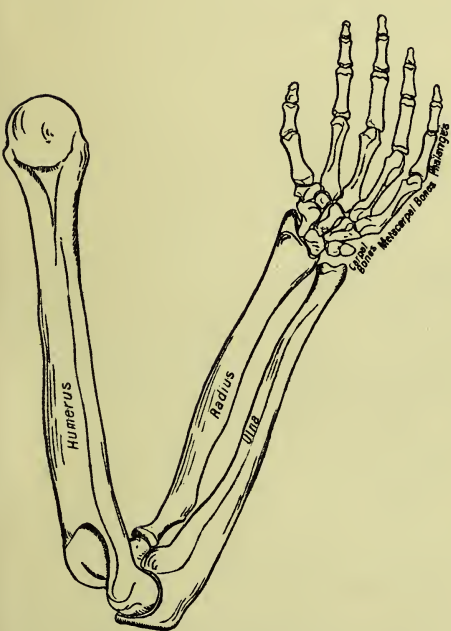


FIG. 16.—Arm and hand.

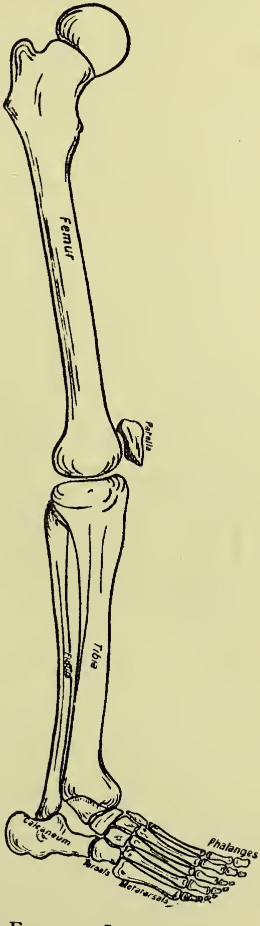


FIG. 17.—Leg and foot.

bones are close set and arranged in two rows. Following the carpals are the five metacarpals of the hand, and in front of these the phalanges of the fingers.

THE RIBS AND STERNUM. **Twelve pairs** of slender, curved bones, the **ribs**, are connected with the twelve thoracic vertebræ; some of the ribs have two points of articulation, i.e., with the body and with the transverse process. The first rib is short, and flat, and practically fixed; it passes from the first thoracic vertebra around at the base of the neck to the top of the breast-bone in front. The **Sternum** or breast-bone in form is like a short sword, 6 to 8 in. in length, situated in the middle

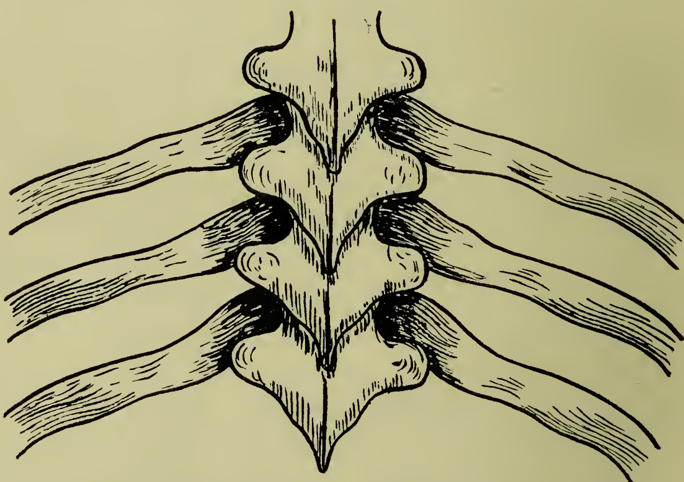


FIG. 18.—Four dorsal vertebræ to show articulation of ribs.

line of the front of the thorax. It is broad at the upper end and the lower end terminates in the ensiform cartilage. The sternum is formed by the union of several bones, and on each side of the sternum are the impressions from the articulations of the cartilages of seven ribs.

The **ribs**, from the first pair to the seventh inclusive, gradually increase in length. These are named **true** ribs; they are connected with the sternum in front by **costal cartilages.** The eighth, ninth, and tenth ribs are indirectly joined to the

sternum, their cartilages joining the cartilage of the rib above. The eleventh and twelfth are not connected in front, but end free and are tipped with costal cartilage. The last five pairs are termed **false** ribs, of which two are **floating** or **free**. Of the twelve pairs of ribs ten pairs sweep round from the thoracic vertebræ and become joined by the flexible costal cartilages to the sternum in front. The bony ribs slope slightly downwards and forwards, whilst the costal cartilages bend sharply upwards to meet the short sternum. In this way the walls of the cone-shaped thorax are formed.

FORMS OF BONES. **Bones** have **three general forms** as found in the skeleton : **broad** and somewhat **flat** in the **head** and **hips** ; **short** and more or less **irregular** in the spine, wrist, and ankle ; long in the limbs and ribs. A total of about 200 make up the adult skeleton, including the patella and the hyoid. The latter is found connected with the root of the tongue.

STRUCTURE OF BONE. Obtain a fresh long bone and make the following observations. The shaft of the bone is invested by a pinkish membrane, named the **Periosteum.** Strip off a piece, it is fibrous and tough, and contains blood vessels. Beneath the periosteum are seen small holes through which the blood vessels enter to nourish the bone. The bone grows in thickness through the medium of the periosteum, and in the case of fracture the bone is renewed by this membrane. The shaft of the bone is a tube of very hard and dense tissue, known as **compact bone**, but the ends show a less compact and more open tissue named **cancellous** or **spongy bone.** The interspaces of cancellous bone contain **red marrow**, whilst enclosed by the shaft is a mass of fatty substance, the **yellow marrow.**

The **ends** of **fresh bone** are covered by **articular cartilage**, a bluish-white, smooth substance. When the end of one bone moves freely over the end of another, each is capped with articular cartilage and the opposing surfaces form a perfect joint. Examine such a joint, and notice that from the **margins** of the

articular surfaces of such bones a membrane forming a kind of **bag** or **sac** is provided. This is named the **synovial membrane** or **sac** and it **secretes** a **thick, sticky fluid,** to lubricate the joint. In addition to these structures, at some joints, for example, the knee-joint, a wedge-shaped piece of tough cartilage, **interarticular cartilage,** is inserted to pack the joint and prevent slipping outwards of the femur.

In the case of young bones, the ends are not at first joined directly to the shaft, but there is an intervening portion of cartilage to allow of the growth of bone in length. When the bone has attained its full length, the cartilage has become changed into bone and the ends united to the shaft. It must be noted that most of the bones of the body are performed in cartilage which later becomes impregnated with mineral substances and undergoes other changes to form bone.

The microscopical features of compact bone are given in Figs. 19, 20.

Experiment 1. Take a slender bone, say the leg or arm-bone of a rabbit, place in water to which a little hydrochloric acid has been added (1 part of acid to 20 parts of water). In a few days the hard bone will have become soft, but remains **tough** and **flexible.**

Experiment 2. Place a similar bone to the above in a red-hot fire ; in a short time the bone will look white or greyish-white. Remove it from the fire, and after cooling it will be found quite **brittle.** The form of the bone has been retained.

These experiments demonstrate that bone is composed of **two substances** : first the mineral, which renders bone hard and can be removed by a weak acid, leaving behind a **tough, flexible** substance or **animal matter.** This latter can be burnt out, and the **brittle** substance left behind is the mineral matter.

Bone is found to be made up of about **one-third of animal and two-thirds of mineral substances.** These together

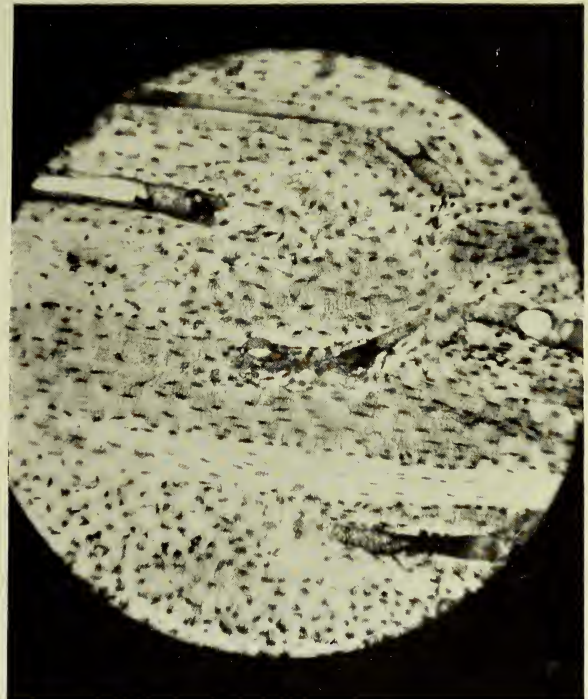


FIG. 19.—LONGITUDINAL SECTION OF BONE. PHOTOMICROGRAPH

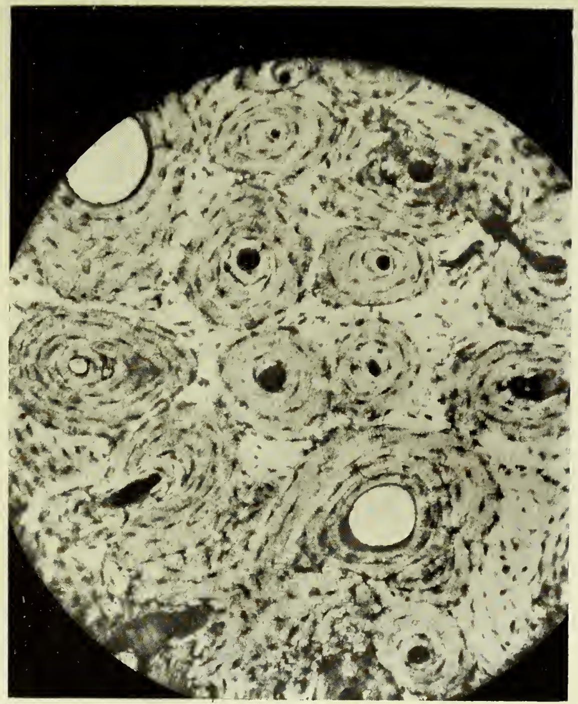


FIG. 20.—TRANSVERSE SECTION OF BONE. PHOTOMICROGRAPH

give to bone the characters of **hardness,** and at the same time **toughness** and a certain amount of **elasticity.**

Composition of Bone.

Animal matter about one-third or 33 per cent.

Mineral substances about two-thirds or 67 per cent, made up of :—

Phosphate of Lime	50	per	cent.
Carbonate of Lime	10	"	"
Other mineral salts	7	"	"
Total	67	"	"

CHAPTER VIII

MUSCULAR TISSUES

The **flesh** of an animal disclosed on removal of the skin is known as **muscular tissue.** The colour is darker or lighter according to the age and nature of the animal examined. The whole of the muscles investing the skeleton is named the **Voluntary Muscular System,** so named because these muscles are under the control of the will. They are also spoken of as **red muscles,** but this term cannot be applied to animals where the **voluntary muscle is white. Striated** or **striped muscle** is another name for voluntary muscle, from the fact that the individual fibres possess fine lines running across them.

To understand the structure of voluntary muscular tissue, a dissection will be helpful. Take the hind-leg of a rabbit, or a small piece from the lower end of a leg of mutton, and make out the following structures. On removal of the skin from the leg of a rabbit, it is noted that the **skin** is **held loosely** by **connective tissue** to the **muscles beneath.** The muscles are **smooth** owing to a covering of connective tissue, and in this are seen **blood vessels** and **fine, white, nerve fibres.** The **muscles vary in form ;** some are like spindles tapering at each end, others are long and strap-like ; others again are broad at one end and narrow at the opposite end. **Each large mass is easily separated into smaller parts or bundles.** Each **bundle** is wrapped with connective tissue, which gives a **silvery appearance** to the outside of the bundle. This appearance is strongly marked near the ends of a bundle where the **connect-**

ive tissue forms **strong, tough bands, named tendons. Tendons serve** to **connect muscle** to **bone** or to **other structures.** The connective tissue serves to cover all the bundles and to pass between the several bundles, which compose a mass **commonly called a muscle.** Blood vessels, nerves, and lymphatic vessels travel to the muscle structure in the medium of the connective tissue. By carefully teasing with needles the end of a small bundle, or better still a piece of muscle that has been hardened, say by salting, it is found to be **composed of small fibres.** A **fibre** is about **1 to $1\frac{1}{2}$ in. in length,** and it has a **diameter of $\frac{1}{500}$ of an inch.** Viewed under the microscope it is found to be enclosed in a membranous sheath, which is named **sarcolemma ;** inside the sheath are **several nuclei.** The fibre is marked **across** by very fine lines, or striations, closely set together. Between the numerous fibres making up a bundle, the capillary blood vessels form looping networks. The **plasma** which passes out of the capillaries **bathes** and **nourishes** the **muscle fibres.** Nerves terminate in close connexion with the individual fibres, and through these nervous impulses travel, which **cause the muscle fibres to contract.**

In addition to the physical property of muscle, that is, the way in which it is built up, it possesses a remarkable **physiological property of contractility.**

Contractility is the power possessed by muscle of becoming shorter and thicker under a stimulus. When a muscle contracts certain changes take place in the individual fibres, resulting in the muscle as a whole becoming shorter in length whilst its thickness is increased. By **contraction** the ends of a muscle are brought nearer together, and if the muscle be attached to a part that is free to move, movement of the part results.

In the body, the **physiological property** of muscular tissue is usually **brought into action** by **impulses which are sent along the nerves.** Other than nervous stimuli, however, can cause muscular tissue to contract ; for instance, to pinch or

gently strike the muscle of a recently killed frog, when the muscle will exhibit contraction. Or a drop of acid applied to the said muscle, or a weak electric current passed into the muscle—either will act as a stimulus to cause contraction.

Involuntary Muscular Tissue. Many movements take place in the organs and tissues of the body besides those due to the presence of voluntary muscular tissue. The walls of the digestive canal contract, and in a series of regular wave-like movements aid the passage of the contents along the canal. The walls of the arteries contract and regulate the discharge of the blood into the capillaries. These **functions are due to the presence of muscular tissue.** The **tissue** is made up of large numbers of very fine spindle-shaped fibres packed closely together. Each fibre is about $\frac{1}{400}$ of an inch **in length** and it has an elongated, slightly granular nucleus. The fibres are of a **pale colour** and **without transverse markings,** and they **are not under the control of the will.** From these three facts, the names **Pale, Plain,** and **Involuntary Muscle** have been applied to this kind of tissue. Pale muscular tissue is found in other parts of the body than those already named.

Cardiac Muscular Tissue. The muscular tissue of the heart is spoken of as **Cardiac Muscle.** It resembles both voluntary and involuntary muscle structures, but it has special features of its own both in structure and function. Its fibres are short and they have short branches. The fibres are of a reddish colour ; they are very finely striated, but are without a sheath of sarcolemma. Each fibre has a single, oval, and slightly granular nucleus, situated in the centre of the fibre. Cardiac muscle fibres are bound together in sheets, and these pass in a spiral manner to form the walls of the heart. **Cardiac muscle has** the **property** of **contracting rhythmically,** that is regularly so many times per minute. The cardiac muscle is influenced by nerves but is not controlled by the will.

Summary. From the study of the skeleton and the muscular system the following considerations may be conveniently summarized :—

Fig. 21.—View of muscles of one side of trunk and limbs.

The **framework** of the body is formed of bones of various sizes and shapes united to form joints. The **unions** or **articulations** are of several kinds, rigid, less rigid, or perfectly free. **Joints facilitate movement. Perfect joints** are supplied with **lubricating fluid**, the ends of the conjoined bones are covered with smooth, **articular cartilage**, and the bones are strongly held in position by **fibrous ligaments.** The flexible material, **cartilage**, not only joins bones together, but it also serves to deepen sockets as in the case of the shoulder and hip-joints, and in other cases to **pack joints** to prevent bones from slipping. Provision for the growth and repair of bone is found in the **periosteum.**

The **voluntary muscles** cover the bony framework and give **outline** to the body. They are attached to the bones by tough, fibrous tendons, through the medium of which the muscles act on the bones which serve as levers in the movements of the parts of the body. The **tendons** are formed from **connective tissue**, which tissue also covers the muscles, giving smoothness, and it further serves as a **support** to the blood vessels, nerves, and lymphatics, as they travel to the ultimate structures of the muscles.

The important **physiological property** of muscular tissue of contractility is aroused by **stimuli** which travel by **nerve fibres** from **nerve centres.**

The **muscles** are of **various forms**, adapted to different parts of the body; some are very small and others are pounds in weight. **Muscles** are not only used in causing motion and locomotion, but by muscular tissue the sense organs are aided, for instance, in tasting, smelling, and seeing. Further, speaking, singing, laughing, weeping, and winking are dependent upon **muscular contraction.**

Names of Muscles. The particular names given to the very large number of muscles making up the voluntary muscular system need not concern us here, but a brief reference to the terms by which muscles are known is necessary. The **volun-**

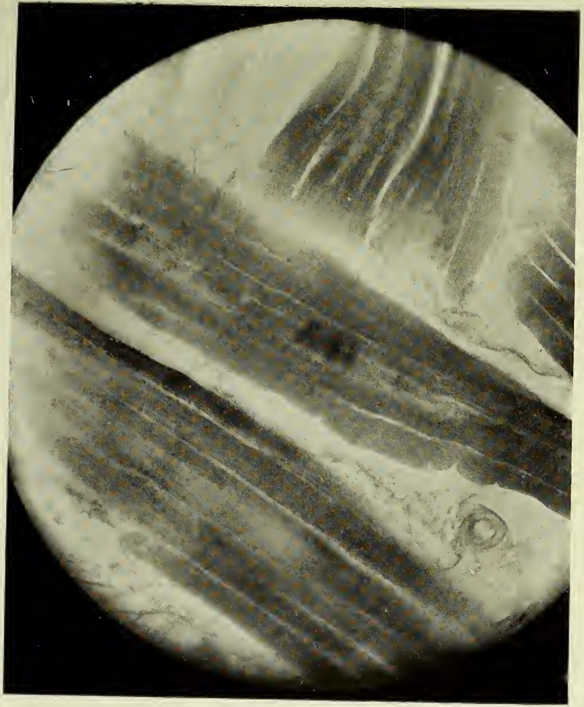


FIG. 22.—VOLUNTARY MUSCLE FIBRES. LONGITUDINAL VIEW. PHOTOMICROGRAPH

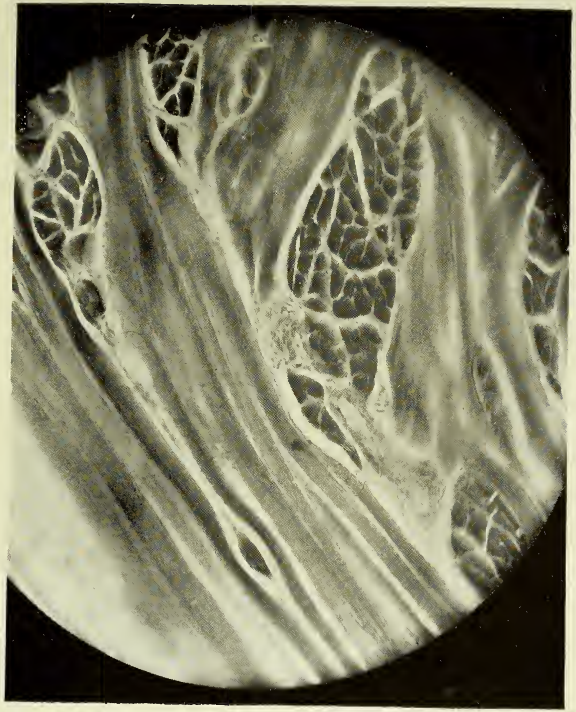


FIG. 23.—VOLUNTARY MUSCLE FIBRES. LONGITUDINAL AND TRANSVERSE. PHOTOMICROGRAPH

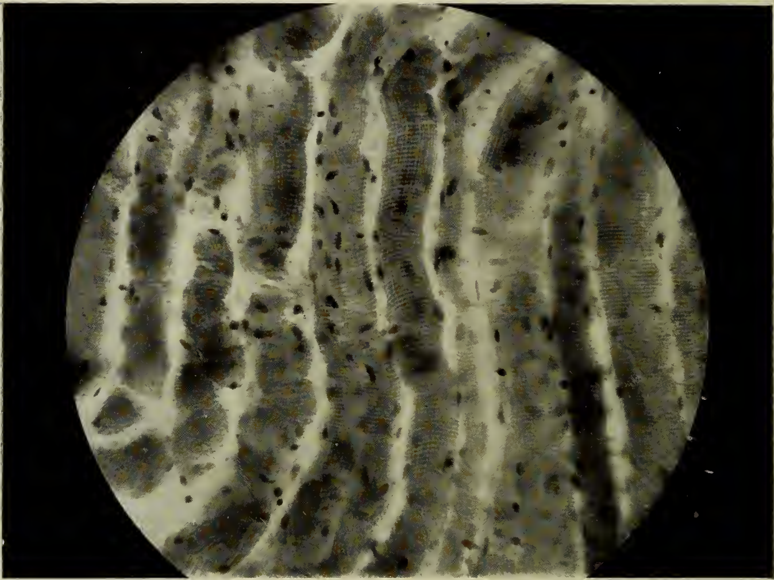


FIG. 24.—VOLUNTARY MUSCLE FIBRES—SHOWING NUCLEI AND STRIATIONS. × 500. PHOTOMICROGRAPH

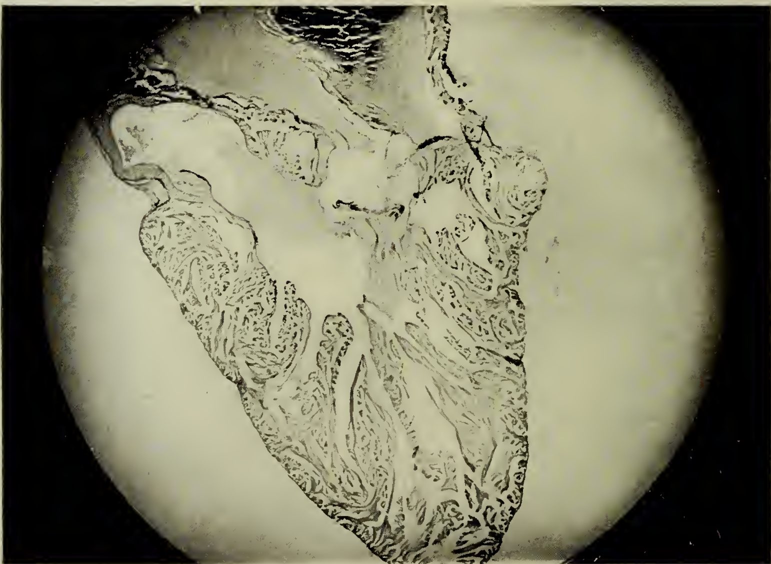


FIG. 25.—LONGITUDINAL SECTION OF FROG'S HEART SHOWING BUNDLES OF MUSCLE FIBRES OF VENTRICLE. PHOTOGRAPH

tary muscles, so named because they are directly acted on by nerve impulses sent to them by an **act of the will.** They are also named **skeletal**, because they cover the skeleton and act upon the bones. The name **red**, which is the colour of the muscles in many animals, but the term is used as opposed to the pale or involuntary muscles.

The **muscles** are well named **striated** or **striped**, because the fibres **viewed** under the **microscope** are seen to have **close-set lines** or **striæ across them.** Other names, such as **flexors** and **extensors**, are applied to muscles according to their action in **extending** or **bending** a part. The **biceps** and **triceps** of the arm are examples of flexors and extensors respectively. The terms **adductors** and **abductors** are used to indicate the muscles engaged in drawing a part **to**, or drawing a part away **from**, another part. The arm is brought to the body by adductors, the thumb is brought near the hand by an adductor muscle, and by abductor muscles these parts are separated or drawn off. In the case of the shoulder and hip-joints, the head of the humerus or the head of the femur performs a circular movement, and this is brought about by muscles named **circumductors.**

The terms **origin** and **insertion** are applied to muscles to indicate the more fixed point and the movable part. A muscle has one or more points of origin; these are **fixed**, or **relatively fixed**, and the muscles pass to be inserted in parts that have **more** or **less** of **movement.** In the case of the triceps of the back of the upper arm, it has three heads or points of insertion—at the scapulæ and humerus—and passes to be inserted at the upper end of the **ulna.** Its action is to extend the lower arm; it is therefore an extensor muscle. Many muscles receive two or more names.

CHAPTER IX

JOINTS—ANIMAL MECHANICS—MOTION AND LOCOMOTION

JOINTS. The **framework of bones** forming the skeleton is broken by **joints** to facilitate movement. A joint is **formed** by the joining or meeting of **two** or **more bones.** The word **articulation** is also used in speaking of the **union** of bones.

Three classes of **joints** or articulations may be noted in the skeleton :—

(*a*) **Immovable.**
(*b*) **Mixed.**
(*c*) **Movable.**

Immovable Joints. The bones are held together by rigid unions which allow practically no movement between the joining bones. Examples have been noted in the unions, by **sutures,** of the bones of the cranium and face; also the **firm union** of the sacrum with the pelvic bones.

Mixed Joints. Where the bone is joined by other substance than bone. **Cartilage,** a tough, flexible structure, is found joining the ends of the ribs to the breast-bone. The **bodies** of the vertebræ are joined one to another by pads or discs of **tough, fibrous cartilage.** The pelvic bones join in front by a tough cartilaginous union. This mode of union of bones admits of a limited amount of **flexibility** and **compressibility** of the parts involved.

Perfect Joints. These unions allow of the **free movement** of the end of one bone over the end of another. In such

joints the ends of the opposing bones are covered with a **smooth, articular cartilage,** and this is provided with a supply of **synovial fluid** to lubricate the joint. The conjoined bones are held together by **tough, fibrous ligaments,** which in some cases form capsules for the joints.

The **perfect joints** are named according to their characters and the particular movements they permit. They are illustrated by the following, **Ball-and-socket, Hinge, Pivot,** and **Gliding joints.**

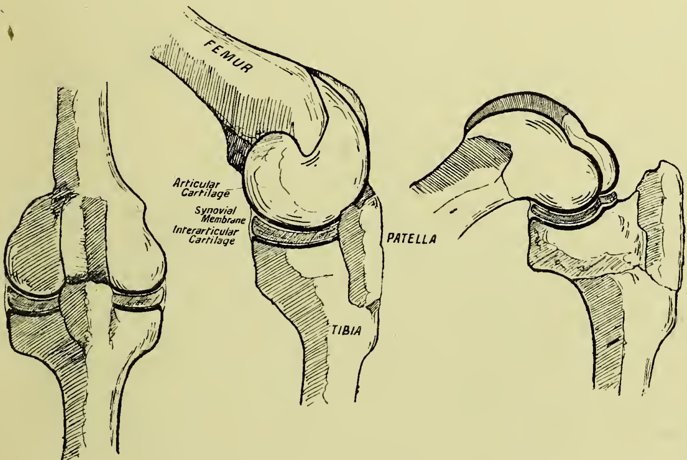


FIG. 26.—Hinge joint. Three positions of knee bones.

Ball-and-socket kind of perfect joints are well shown in the shoulders and hips. The shoulder-joint has a relatively shallow cup, the **glenoid** cavity of the shoulder-blade, which receives the rounded head of the humerus. The **movements** at the shoulder are **perfectly free** in **every direction.** The hip-joint formed by the rounded head of the femur articulating in the **deep cup** or **acetabulum** of the pelvic bone. The head of the femur has a **round ligament** passing from its centre to the bottom of the cup, whilst on the outside the

head is enclosed by the capsular ligament. The **movement** at the hip-joint is **more restricted** than that at the shoulder.

The **Hinge joint** is another illustration of the perfect kind in which the **movement** is limited to **one plane**, to and fro, like a door on its hinges.

Examples of hinge joints. The articulation of the **condyles** of the **occipital** bone on the **atlas** vertebra which permits of the nodding of the head.

The **elbow-joint.** The lower end of the humerus fits into a deep groove at the upper end of the ulna and allows of the **flexion** and **extension** of the lower arm. In the case of the knee-joint, the **large condyles** at the lower end of the femur articulate with the **broad surfaces** at the upper end of the tibia. Other illustrations of hinge joints are found at the fingers and toes.

Pivot joints allow of movement of rotation. The turning of the head from side to side is permitted by the movement of the **first vertebra**, the **atlas**, **part way around** the **odontoid peg** of the **second vertebra**, the **axis.** Another pivot joint is met with in the case of the **small end** of the radius against the **lower end** of the humerus; the small end of the radius at the same time turns by its side in a groove at the upper end of the ulna. Both these movements take place when the **palm of the hand** is **turned downwards**, i.e. in **pronation. Shallow pivot joints** are formed by the articulation of the metacarpal bones with the first bone of each finger.

At the wrist and ankle, by the **grouping** of the carpal and tarsal bones, a series of **Gliding joints** are formed. All the carpal and tarsal bones are provided with smooth, articular cartilage and lubricated by synovial fluid, and a limited gliding movement takes place among the short bones. The articulation of the metacarpal bone of the thumb with the trapezium of the carpal bones forms a **double hinge** or **saddle joint.** This allows a **double movement** of the thumb, i.e., to and fro, and side to side.

By reference to the several figures of the bones the examples will be readily understood.

ANIMAL MECHANICS. The term **motion** is used in speaking of the movement of a part of the body, and **locomotion** implies the movement of the body as a whole from place to place. The structures concerned in motion and locomotion are the muscles and bones. These form levers, the bones serving as rigid bars acted on by the muscles.

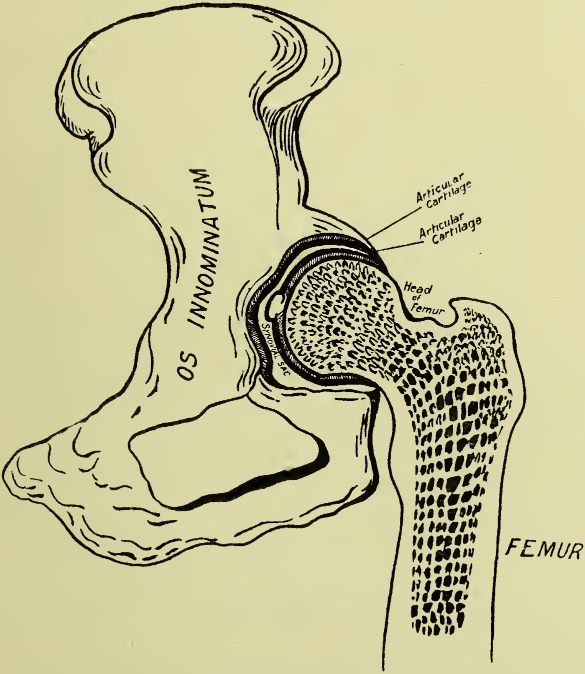


FIG. 27.—Ball and socket joint of hip.

Look upon a lever as a rigid structure with **one end or part relatively fixed**, whilst the **other end or part is free to move.** Next recognize the three parts of a lever :—

1. **Fulcrum**, or fixed point, indicated by F.
2. **Power**, or moving force, indicated by P.
3. **Weight**, or resistance to be overcome, indicated by W.

The **relative positions** of these three parts give three orders of levers.

1st Order. P, F, W, when the **fulcrum** comes between the **weight** or **resistance** and the power.

2nd Order. P, W, F, the **W between the P and F.**

3rd Order. F, P, W, the **P between the W and F.**

In the many movements of the body we constantly employ

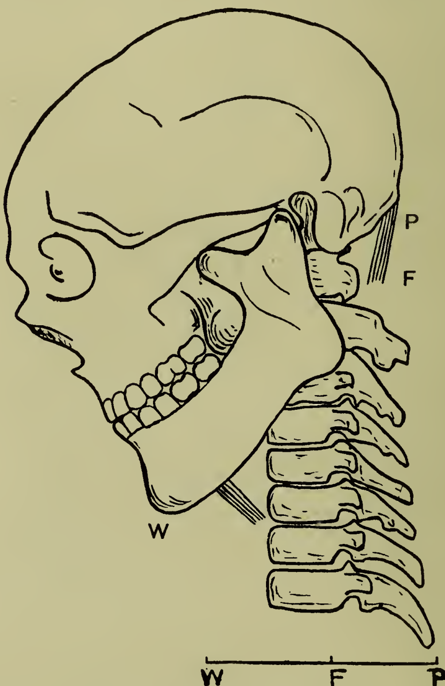


FIG. 28.—Lever of the first order.

the three kinds of levers. The muscles acting as the P or moving force to overcome some resistance or W.

A **lever** of the **first order** is brought into play in the following movements of the body :—

Nodding the Head. F = the articulation of the occipital condyles on the atlas vertebra. P = the action of the muscles at the back of the neck, or the action of the muscles in the front of the neck. W = the weight of the head. Another example is seen in raising the trunk to the erect position after bending forward. F, at the hip-joints; W, the trunk; P, the force of the large muscles at the buttocks. The **extension** of the **lower**

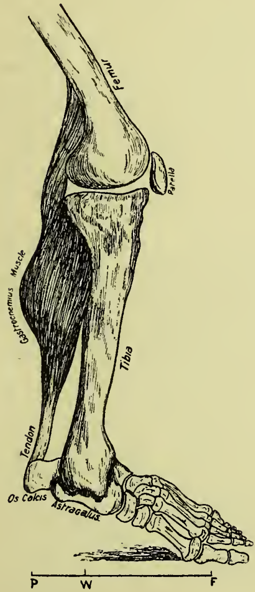


FIG. 29.—Lever of the second order.

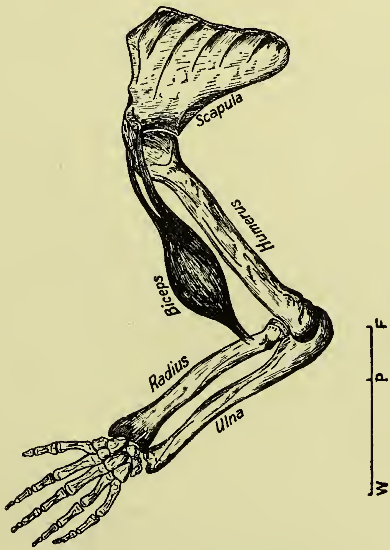


FIG. 30.—Lever of the third order.

arm is done by a lever of the first order. The triceps muscle at the back of the humerus has its tendon inserted into the olecranon process at the end of the ulna, and this is the point of application of P. The F is the articulation at the elbow, and the W is the lower arm.

The **extension** of the **lower leg** is a further example of a lever of the first order. P = the action of the large extensor muscle at the thigh, the insertion of which is near the upper end of the tibia, just below the patella ; F = the articulation at the knee-joint ; W = the lower leg.

Levers of the Second Order, P, W, F. Examples in the body, first, opening of the mouth by depressing the lower jaw. P = the action of the digastric muscle attached just within the chin ; F = the articulation of the condyles of the lower jaw with the temporal bones ; W = the **resistance** of the lower jaw. A second example of this order of lever is exhibited when the **heel is raised** and the **toes rest** upon the ground. P = the action of the large muscle of the calf acting on the heel-bone through the tendon of Achilles ; F = the **resistance** of the toes at the ground ; W = the weight of the body transmitted through the tibia to the tarsal-bones.

Levers of the Third Order, F, P, W. This order of levers is well illustrated by the **bending or flexion** of the limbs. In the flexion of the lower arm on the upper arm by the action of the biceps, F is the elbow-joint ; the application of P is at the radius just in front of the bend of the arm. W is the weight of the arm in front of the insertion of the tendon of the biceps into the radius. The **flexion** of the **lower leg** is another example of this order of levers ; F at the knee-joint ; P is applied just below and behind the knee joint by the action of the muscles at the back of the thigh ; W is the weight of the lower leg. A further example is seen in the **closure of the mouth**. F is the articulation of the lower jaw with the temporal bone ; P is the action of the temporal masseter muscles at the sides of the jaw ; W is the resistance of the jaw on being raised.

The student unfamiliar with mechanics will find it easy to remember the parts, and the relative positions of the parts of the three orders of levers, by keeping in mind three familiar illustrations of these levers out of the body.

First Order. The act of stirring the fire with a poker.

Second Order. The wheeling of a wheel-barrow, or the act of cutting with a pair of scissors.

Third Order. The raising of a ladder, or the removal of a clothes-prop.

MOTION AND LOCOMOTION. The many and varied movements of the body are largely due to the employment of the three kinds of levers, either to move parts of the body, or to move the body as a whole.

Standing. The erect position demands the contraction of opposing sets of muscles at the back and front of the body. The bony framework and its ligaments of itself is not able to maintain the erect position ; it is the muscular system, which clothes this framework, that gives **substance** and **support to the body.** If the muscles at the back of the trunk and limbs contract without the counteraction of those at the front, the body will be thrown backwards. The leg is **kept straight** for support by **antagonizing** sets of muscles. That which now is perfectly easy to perform, to stand erect, was not always so. Observe the young child striving to gain the erect position and to stand alone. Much effort is expended and much practice is demanded. The numerous muscles must act in harmony to enable the child to stand without support.

Walking and Running consist in a series of muscular actions to bring about a **bending** and **straightening** of the legs and a **pressing** of the **feet against** the **ground,** or some other resisting surface. Each step involves the contraction of the large muscles of the calf, and by its tendon acting on the heel-bone the heel is raised and the toes are pressed against the ground. The foot leaves the ground and the leg swings pendulum-like forward to plant the foot on the ground a step in advance, whilst the other foot is preparing to leave the ground. As each step is taken, we notice the bending at the knee, followed by a straightening of the leg and the pressing of the foot on a **resisting surface.** There is a tendency, as each step is taken, for the body to be thrown to one side, but as the foot lands the

body is righted, only to be thrown again, now to the other side, and so on for successive steps taken.

Next quicken the pace and observe how rapidly the muscles of the calf and the muscles of the thigh act to raise the heel and to bend and straighten the leg. To pass from **quick walking** to **actual running,** it will be noticed that one foot is actually off the ground before the other reaches it. With successive steps there is a graceful rise and fall of the body, like a series of undulations, well marked in steady walking and becoming less obvious in the rapid motion of running.

In this connexion the **act of jumping** may be seen to consist of a bending and straightening of the body and a **pushing against** a **resistance.** For a moment, the body is observed **to be compressed** at the joints like a spring, and when all is ready for the jump the **force** of the **will** is **thrown** into the muscles involved and a **vigorous contraction** follows ; the limbs are **straightened** and a **forceful** but **elastic spring** is **taken.**

CHAPTER X

THE HEART

The **Heart** is a cone-shaped, muscular organ, dark red in colour, and situated beneath the sternum in the thorax and between the two lungs. The apex of the heart is to the left of the sternum, and points to the space between the fifth and sixth ribs just below the left nipple; the base or broad end of the heart is upwards and backwards.

The **Pericardium,** a thin connective tissue membrane, covers the heart. The pericardium is a double membrane; a portion closely and completely invests the surface of the heart as far as the large blood vessels, it is then reflected over the heart to the apex as a **loose layer** or **bag.** The pericardial bag encloses a pale yellow fluid between the two layers of membrane, and the pericardial fluid serves to reduce friction during the working of the heart.

The **human heart** is about 5 in. in length, $3\frac{1}{2}$ in. broad, and $2\frac{1}{2}$ in. thick, and is roughly compared, as regards size, to the closed fist of the owner. It weighs in the adult male 10 to 12 oz. and in the adult female 8 to 10 oz. The heart is a **hollow, muscular organ,** but feels almost solid owing to the thickness of its walls.

Examine the thorax of a rabbit after removal of the front wall; the heart is seen in position between the lungs. The pressure of air upon the lungs after removal of the wall has caused the lungs to shrink, and the heart and the pericardial bag will be well exposed. Insert a piece of glass tubing into the windpipe and blow up the lungs. When fully distended

they close over the heart in front. The **examination** and **dissection** of a sheep's heart, as well as **seeing** the **position** of the organ in the rabbit, will be helpful in understanding what follows.

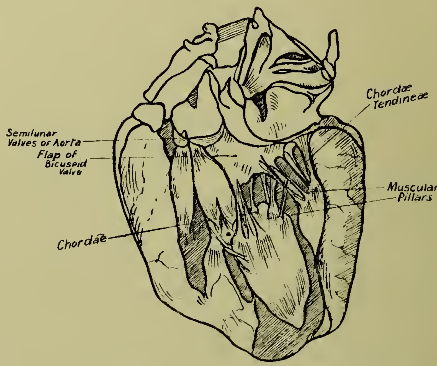


FIG. 31.—Sheep's heart showing valves of left ventricle.

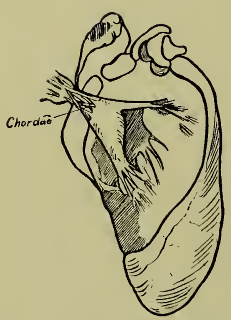


FIG. 32.—Sheep's heart showing valves of right ventricle.

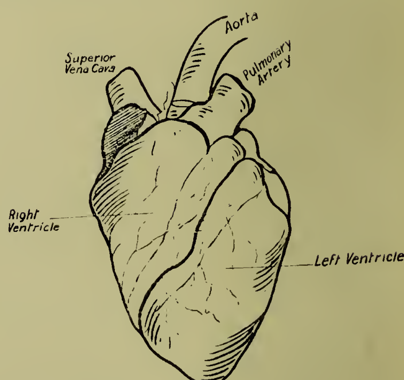


FIG. 33.—Front view of sheep's heart.

Procure a sheep's heart and make the following observations and dissection: Colour. Form. Base. Apex. Firmness of one side compared with the other. Surface smooth, but marked by more or less of white fat.

The more convex surface is in the front, it has a groove running from right to left, and the apex is wholly below this groove. Lines of fat bound the groove and a blood vessel is seen at the bottom. Another groove runs across the top with much fat; above this on the right is seen an ear-like flap and on the left another flap, but barely seen when the front portion of the heart is in view. Between these two flaps at the upper end of the heart is a large artery, **pulmonary.** Immediately behind the first is a large, thick-walled artery, the **aorta**; it **appears** to arise from the centre of the base. Now looking down upon the base, on the left near the aorta, may be found a large, dark-red tube, nearly closed; this opens into the right upper chamber, whilst lower down at the back of this chamber may be noted another similar tube entering sideways. These are large veins, **superior** and **inferior venæ cavæ.** Other two vessels or their openings may be found at the upper end on the left side with the back of the heart facing you, the **pulmonary veins** opening into the left auricle. Next by cutting into the heart along the groove running from right to left a solid, thick, muscular wall is exposed. This divides the heart into right and left sides, giving an upper and lower chamber to each: **right auricle** and **right ventricle,** and **left auricle** and **left ventricle.** By cutting carefully around the groove between each auricle and ventricle, without entirely separating the parts, the opening from the auricle to the ventricle may be seen, and attached to the margin of each opening hanging into the ventricle are flaps of membrane. (Figs. 31-32.)

The right side of the heart is **entirely shut off** from the left by a thick muscular partition. Each side has an upper chamber leading into a lower through an opening, and from its position between the auricle and ventricle is named the **auriculo-ventricular aperture.** On the right this is guarded by **three flaps** of **membrane** forming the **tricuspid** valve, and on the left **two flaps** form the **bicuspid** or **mitral** valve. **These valves form partitions** between the auricles and ventricles

only when the blood has passed from the auricles to the ventricles and filled the latter; the flaps forming the valves have then **floated up** as a **barrier** across each auriculo-ventricular aperture. Now open up the auricles and ventricles by cutting along a line close to the middle wall. The **interior** of all four chambers is rendered smooth by a lining of **endocardium** membrane; the **walls** of the ventricles **are uneven,** and the projections of the muscular walls afford attachment for **strong tendinous cords,** which by their opposite ends are let into the flaps of the valves. The **tricuspid** is seen to have three somewhat triangular flaps with pointed ends, whilst the two flaps of the **bicuspid** are **broader, stronger,** and less **pointed.** On the left side, not only are the valves and attached cords stronger, but the **wall** of the **left ventricle** is **more than twice** as **thick** as the wall of the **right ventricle.** The **walls** of the **auricles** are **much thinner,** and the inside exhibits an **interlacing network** of **bundles** of **muscle fibres,** particularly in each appendix of the auricle. This open network gives additional space to the auricles, making the capacity of the auricles to be equal to that of the ventricles, although the auricles look much smaller. The spaces inside the ventricles look very limited, that of the left ventricle particularly so, and this is clearly due to the great thickness of the walls, readily seen in a **section across** the ventricles.

Next, trace the openings of the pulmonary artery from the top of the right ventricle. Place a probe down the artery and slit it open at the point of junction with the ventricle. Now are seen **three half-moon shaped flaps** of membrane around the inside of the artery—the **semi-lunar valves.** They are attached to the inside of the artery, but with one border free. Press each one out and **realize how by meeting together in the centre,** due to the pressure of the blood, **these three flaps form a barrier** to the return of the blood after it has been forced into the artery from the ventricle. The opening to the pulmonary artery is behind a flap of the tricuspid valve. Insert a rod in

the **aorta** and notice that the rod passes into the left ventricle; open out the aorta down to its junction with the ventricle and note three flaps forming the **semi-lunar valves of the aorta.** When the blood is forced from the left ventricle, its return is prevented by the opening out of the flaps across the artery. The valves are now said to be **closed against** the return of the blood; the next contraction of the ventricle will force them open, and they will be **pressed against** the **inside** of the **aorta.** A similar action takes place with the semi-lunar valves at the **outlet** of the **pulmonary artery** from the **right ventricle.**

It should be noted that just above two of the flaps of the semi-lunar valves of the aorta are the openings of the **coronary arteries**; these supply the substance of the heart, and the one coronary vein may be seen opening into the right auricle, protected by a fold of the lining of the heart forming the **coronary valve,** between the opening of the inferior vena cava and the aperture into the ventricle.

The **mouth** of the **inferior vena cava** also has a **partial valvular fold** of membrane, whilst the **first** portion of the **superior vena cava** is a continuation of the muscular wall of the right auricle, and upon the contraction of the right auricle this serves to prevent the return of the blood into the vein.

CHAPTER XI

THE BLOOD VESSELS AND CIRCULATION

The heart, situated in the thorax, receives blood by a system of tubes or vessels, and pumps the blood into another set of vessels, and between these there is a third set. The blood vessels are conveniently described as arteries, veins, and capillaries. **Arteries** are vessels which carry blood from the heart to all parts of the body; **veins** are vessels which return the blood from all parts of the body to the heart; **capillaries** are vessels which come between arteries and veins. The latter distribute nourishment to the tissues, and also take up waste matters. The blood is continually circulating from the heart into the arteries, then entering the capillaries, and finally reaching the heart through the veins.

The **main artery**, the **Aorta**, arises from the upper part of the left ventricle; it proceeds a little way towards the upper part of the thorax, forms an arch, bends downwards through the thorax near the back-bone; passes through the diaphragm, thence it finds its way down the abdomen and divides into two main branches, one to each leg. From the arch of the aorta four branches arise, namely, two carotid arteries and two subclavian. The **carotids** pass up the neck and supply the head and the brain with blood, whilst the **subclavians** and their branches supply the parts of the arms. By branches from the descending aorta, all parts of the thorax, abdomen, and lower limbs are supplied. Following this frequent branching of the main artery, the arteries diminish in size from about

$\frac{3}{4}$ of an inch to, as small as, $\frac{1}{2500}$th or $\frac{1}{3000}$th of an inch in diameter. When so reduced in size they become capillaries. We must not, however, think of the aorta having to pass through all this reduction in size as a whole, but to remember that the larger branches rapidly give off small branches, and these further suffer a rapid reduction, and the very smallest arteries pass into capillaries. The capillaries are exceedingly

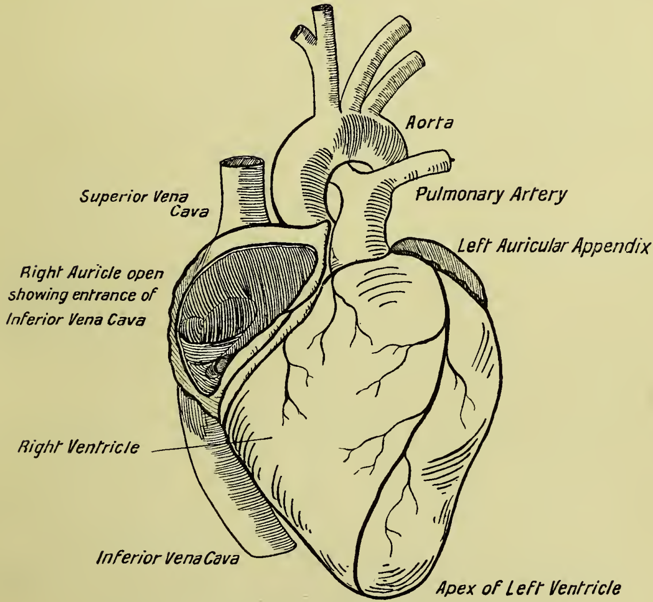


FIG. 34.—The heart and large blood-vessels.

numerous, occupying nearly every tissue of the body in close networks, so much so that the slightest pin-prick draws blood from them. From these numerous capillaries arise the smallest veins, about as small as the capillaries at their beginnings. By frequent unions the small veins form into larger ones, and finally the veins from all parts of the tissues end in two large trunks, one the superior vena cava, which returns all the blood

to the heart from the head, neck, and upper limbs, and another, the inferior vena cava, which returns the blood to the heart from all parts below, the lower limbs, abdomen, and thorax.

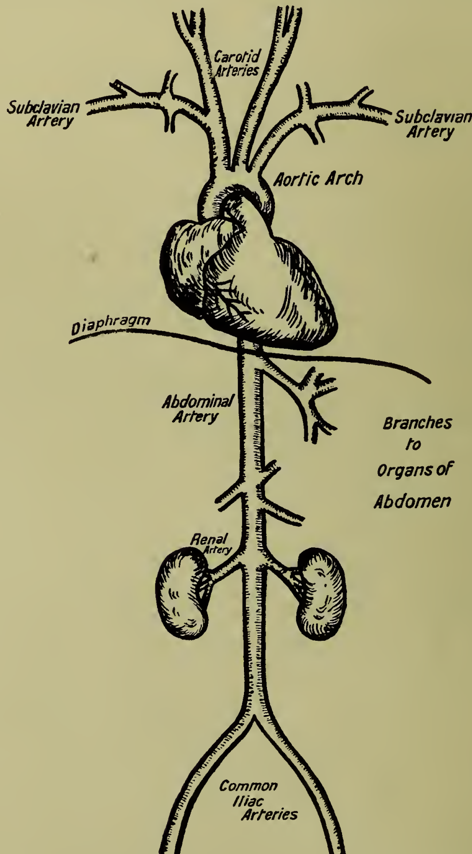


Fig. 35.—The heart with aorta and chief branches.

The blood that has circulated to nourish the substance of the heart is gathered into a vein, the coronary, which opens into the right auricle near where the inferior vena cava opens,

and a little distance from the opening of the superior vena cava. By **these three channels** all the blood finds its way back to the **right auricle** of the heart. The passage of the blood from the left side of the heart into the aorta, and by means of its branches

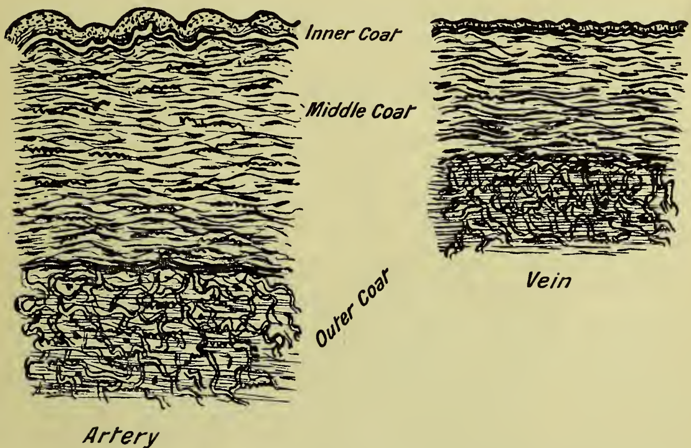


FIG. 36. - Structure of artery and vein—sketched from the microscope.

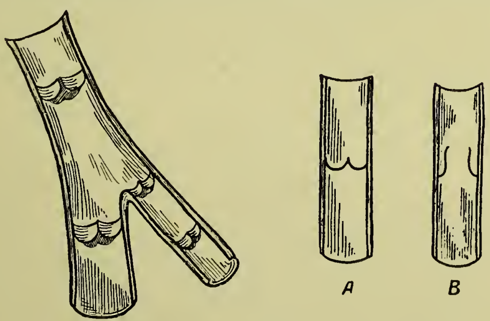


FIG. 37.—Section of vein showing valves.
A, Closed; B, Open.

reaching every organ and tissue of the body, thence into the capillaries and from these into the smallest veins, these again into larger veins and finally into the heart itself by **two venæ**

cavæ and the **coronary vein,** completes the **greater** or **systemic circulation.**

The **Portal Circulation** is a branch of the systemic circulation. After the blood has circulated in the stomach, intestines, spleen, and pancreas, it is gathered into a large vein, the **Portal vein,** formed by the union of the veins from these organs. The portal vein now enters the liver, and the blood circulates a second time through capillaries which run amidst the liver cells. Thus instead of the blood **passing directly** into the inferior vena cava from the above-named organs, it is

FIG. 38.—Skin of frog's foot, showing the course of the circulation of the blood.

first made to circulate through the liver, and during its passage certain things are removed from the blood by the liver cells before it enters the general circulation. It must be remembered that the liver has a supply of blood from the systemic circulation like every other organ of the body, as well as the portal supply just indicated.

Pulmonary Circulation. The blood having returned to the right auricle of the heart, it passes into the right ventricle, and is then forced into the pulmonary artery, proceeding by right and left branches to the lungs. It next passes into **close-**

set capillaries which are distributed all over the **air-sacs** of the lungs. From the capillaries arise the finest veins, and these, becoming larger by frequent unions, finally leave the lungs as pulmonary veins ; **four** in the case of the human subject, but only **two** in the case of sheep. These veins open into the left auricle, thus completing the **pulmonary** or **lesser circulation.**

It is now necessary to consider the structures of the blood vessels in order to understand **how the blood is kept circulating.**

Arteries are strong, tough, flexible tubes—a little **pressure** will cause the structure to stretch, and upon the release of the pressure **recoil** takes place, showing that they are elastic as well as tough. Take a piece of the large artery running as a white tube down the inside of a sheep near the back-bone, or a piece of one of the arteries from the base of a sheep's heart—test it as suggested above ; next, notice that the **artery** has **three layers** or **coats,** not difficult to peel off. An outer coat of rather **loose connective tissue ;** a **middle coat, thick,** and made up of **elastic** and **muscular tissue ;** and a **thin,** smooth, **epithelial coat** on the inner side, resting upon elastic tissue.

Microscopical examination of the coats of the arteries is necessary in order to determine the nature of the structures present. Compared with the larger arteries it is found that the **smaller arteries** have **proportionately more muscular** and **less elastic** tissue present in their walls.

The muscular tissue is supplied with nerves, and it **serves** to **regulate** the **size** of the **outlet** into the **capillaries.** In this way the **quantity** of **blood** passing into an organ or tissue **is controlled** according to **requirements** of the **tissue.** The larger arteries, and especially those near the heart, **possess more** of the **elastic element** to allow of distension and so accommodate more blood forced into them by successive contractions of the heart. Between two contractions of the heart the pressure is less, and the **stretched elastic tissue**

recoils and **presses onward** the blood contained in the arteries, or in other words, the elastic recoil helps to **maintain** the **circulation.** It does more, it helps to convert the **intermittent pumping** of the blood by the heart into the arteries into a **continuous stream** of blood into the capillaries.

Veins are **similar in structure to arteries. Three coats,** the outer, middle, and inner, are present, but the quantity of muscular and elastic tissue is less, and veins are accordingly thinner in their walls. When empty the walls of veins collapse or come together, whereas in the case of arteries with thicker walls, they stand open under similar conditions, a fact to be noted when dissecting an animal.

If the interior walls of the veins, especially those subject to pressure, be examined, small **pocket-like valves** will be found usually arranged in pairs. The **free border** or mouth of **each valve faces the way the blood is flowing,** that is, in the direction of the heart.

Press on the **superficial veins** of the **skin** of the back of the hand or arm and note the slight swelling in knots behind the seat of pressure. The interference of the onward flow of blood has brought the little pocket valves out from the sides of the vessel to **form a barrier.** When the pressure is removed the knotted appearance of the vessel disappears.

Valves are **absent** from **arteries, except** in **two cases ;** the **aorta** and **pulmonary** artery at their junctions with the heart, where each has three semi-lunar valves. **Valves** of the **veins** and **valves** of the **heart** are so placed as **to prevent** the flow of blood proceeding other than in one direction. It can flow from auricle to ventricle, from ventricle into arteries, through capillaries and onward through the veins to the right side of the heart.

Veins are **more numerous** than **arteries** and are arranged in two sets : superficial, those immediately below the skin, and a set, situated deeper in the tissue and running in company with the arteries, often in pairs. Both arteries and veins have frequent

joinings which ensure the passage of blood under temporary pressure. Arteries are **better protected** than **veins** as a rule, they run deeper, and they are often protected by being on the inner side of bones.

The **structure** of a **capillary** is simple, being composed of a **single layer** of **epithelial cells**, held together at their edges in such a manner as to be **permeable** to the passage of **liquids** and **gases**. The average diameter of a capillary is about $\frac{1}{3000}$th of an inch. Capillaries are arranged in networks in the midst of the minute structures of all the organs of the body. To examine under the microscope a piece of tissue which has had the vessels injected with a coloured substance, is to look upon a close network of coloured lines running intimately between the cells and fibres of all the tissues. The capillaries are vastly more numerous than either arteries or veins. When seen in the living tissues, such as the tail of a tadpole or the web of a frog's foot, the **capillaries form** an **intimate meshwork connecting arteries** and **veins**. In such a view the oval, coloured blood cells are seen in striking procession and order, passing quickly along a colourless liquid stream of plasma, whilst the colourless blood cells may be seen clinging to the inside of the vessels.

CHAPTER XII

THE HEART IN ACTION

In the preceding chapters the heart and blood vessels, their several structures and arrangement of parts, have been considered. If the suggestions for observation and simple dissection have been followed, the present chapter will be the more readily understood. Neglect to examine the chambers of the heart, the appearance and attachment of the valves, the connexions of the larger blood vessels with the heart and their more obvious characters, will lead to a failure to appreciate the teaching of this chapter.

Beat of the Heart. From the beginning to the end of life the heart beats. The impact may be felt between the fifth and sixth ribs, a little to the left of the sternum; or the number of beats may be ascertained by counting the pulse felt above the lower end of the radius. In the healthy adult the pulse is felt 70 to 75 times per minute. The heart then is beating or distending and contracting this number of times every minute. The number will slightly vary in different positions of the body; during rest, in sleep, and in reclining positions there are fewer beats per minute, whilst in active conditions of the body and under excitement the number of beats will increase.

Consider the heart in its position in the thorax receiving blood on the right side into the right auricle from the superior and inferior venæ cavæ and coronary vein, and on the left side into the left auricle from the pulmonary veins. From the auricles some of the blood passes straight through the auriculo-ventricular apertures into the ventricles. The ventricles

are distending to receive the full quantity which is now being pressed in under the contraction of the auricles. The auricles contract just as the ventricles complete their distension. The blood passed into the ventricles has caused the bicuspid and tricuspid or auriculo-ventricular valves to float up and close off the passages from the ventricles into the auricles. The flaps of these valves are held in position and kept from going too far by the tightening of the tendinous cords. The ventricles are filled with blood, and their muscular walls contract in a somewhat spiral manner, pressing on the contained blood. The blood must either go back into the auricles or onward into the aorta and pulmonary artery. It cannot return, and in order to enter the aorta from the left ventricle and the pulmonary artery from the right ventricle, the pressure on the blood must be sufficient to force open the semi-lunar valves at the junction of each of these vessels. This is done; the flaps of membrane forming the semi-lunar valves at the entrance to the aorta and pulmonary artery when pressed against the sides are said to be **open**, and the blood escapes; that from the right ventricle into the pulmonary artery and that from the left ventricle into the aorta. Remember that as soon as the ventricles cease to contract they open out again, and the blood from the aorta and pulmonary artery has a tendency to rush back into the ventricles, and in doing so the flaps or pockets forming the semi-lunar valves are thrust out from the sides across the bore of the vessels—**they form a barrier**, and the valves are said to be **closed**. Whilst this is taking place the auricles have been filled, some blood passed into the ventricles through the auriculo-ventricular apertures, the contraction of the auricles, the complete discharge into the ventricles, closure of the bicuspid and tricuspid valves, and the contraction of the ventricles once more. At each contraction of the ventricles, about 3 fluid oz. of blood are pumped into the aorta from the left and a similar quantity into the pulmonary artery from the right ventricle. Like quantities are received by the auricles.

Sounds of the heart. During the beat of the heart there may be heard by aid of a stethoscope two sounds. The first sound, known as a dull, heavy sound, is probably due to the vibration of the bicuspid and tricuspid valves on closing, and in part to the sound emitted by the muscular walls of the ventricles on contracting. The second sound is short and sharp, and has been shown to be caused by the closure of the semi-lunar valves.

The heart may be regarded as a **muscular pump**, receiving and pumping blood. The blood received into the right auricle returns from all parts of the body as impure or venous blood, and some of its impurities have to be excreted by the lungs, **particularly the gas, carbon dioxide.** The blood therefore passes from right auricle to right ventricle, and by the contraction of the right ventricle is forced into the pulmonary artery, which at once divides into two branches and conveys the venous blood to the lungs to be **purified** and returned by the **pulmonary veins** to the **left auricle.** By the contraction of the left auricle the purified blood, arterial, passes into the left ventricle, thence into the aorta. This main artery gives off branches to all parts of the body. Whilst the heart acts as a muscular pump the blood vessels serve as **distributing tubes,** and, carefully note, a system of **closed tubes.** The arteries open out of the heart, a closed pump, and the veins open into the heart; the blood is therefore **kept circulating** from heart to arteries and by veins back to the heart. Consider now only the aorta and its branches. The heart by its muscular contraction forces about 3 oz. of blood into the **already full arteries.** In order to accommodate the extra quantity, the walls of the arteries, beginning with the aorta, **distend by virtue of the elastic tissue present;** the semi-lunar valves behind are closed for the moment until the next contraction of the ventricle takes place and more blood is forced into the aorta. Immediately after the elastic tissue of the aorta has been stretched by the pressure of blood, it **recoils** or comes

back, and in doing so **presses on the blood** and the pressure forces it forward into the capillaries. The muscular tissue in the smaller arteries, by the action of **nerves named vaso-motor,** keeps them in a state of tension and **regulates** the **quantity** of blood that shall pass into the tissues of the body at any one time according to requirements.

In **blushing,** what happens is that the smaller arteries relax their tension, that is, the muscular tissue is relaxed, and **more blood flows** into the capillaries and gives the skin a **suffused red appearance** and a **feeling** of **warmth.** If in turn the muscular tissue in the walls of the smaller arteries contracts more than usual, then the **quantity** of **blood passing** is **restricted** or reduced and the skin looks **pale** and **feels cold** ; this condition is known as **pallor.** Careful attention to the explanation of blushing and pallor enables the student to see the important use of the regulating action of the muscular tissue of the arteries. In the case of an organ or tissue requiring more blood to meet the needs of greater activity, it comes into play by relaxing ; or there may be less blood required to a part ; again the regulation action of the muscular coat comes into play, this time by contraction.

Blood Pressure. To understand the action of the **elastic tissue** found freely in the larger arteries, return to what happens to the aorta when the left ventricle contracts and forces **more blood** into the **already full artery.** The blood in the artery is partly pushed forward by the pressure, but most of the pressure is expended in distending the elastic tissue of the walls, and this pressure is spoken of as **blood pressure.** This pressure passes along the arteries as the blood is pushed forward, but decreases in force the farther it gets from the beginning of the aorta. The heart then acting as a pump, forces a given quantity of blood into tubes with elastic walls and **causes** their **distension** ; and the **recoil** of the walls presses on the stream of blood, pressing it into the myriads of capillaries, thence to the veins, during which **blood pressure** has become greatly reduced. If the

smaller arteries are unduly contracted, the blood leaves the arteries less freely, and blood pressure becomes **high**; this might lead to a strain on the heart. Blood pressure will be **lowered** if the outflow of blood into the capillaries be freer. From this brief consideration we see the value of the elasticity in the arteries, especially in those situated near the heart. The blood is maintained in its circulation by its recoil, and its distension depends more or less upon blood pressure; and, moreover, the condition of the smaller arteries in regulating the outflow has much to do with high and low blood pressure.

The Pulse. We feel the pulse at the wrist as a rule, because it is convenient to feel it there. It may, however, be felt at any part of the body where the arteries come near enough to the surface. It feels like a pressing up and a falling away of some yielding structure repeated so freely that it is at first difficult to count the number of **elevations.** Try for half a minute; the number will be probably 35 to 37, or at the rate of 70 to 75 per minute. Exert yourself, the number is increased; next sit quietly for a time, and you may recognize a slight decrease in the number. This slight elevation of the arterial wall is felt each time the heart beats, and is due to the **overfilling** of the **arteries.** When the left ventricle contracts and forces a given quantity of blood into the already full arteries, there is distension of the walls of the arteries beginning with the aorta, and a wave-like motion passes along the whole of the arteries causing a slight momentary elevation, followed by another and so on in quick succession. It is not the whole volume of blood in the aorta pushed forward that is felt, but a **wave of distension of the walls making them firmer.** The distension of the aorta will be greatest, in other words, the strongest pulse will be at the aorta, and as the wave of distension proceeds, the pulsation diminishes in intensity until it is practically lost in the capillaries. The **pulse wave travelling** over the **arterial walls is rapid,** whilst the **actual velocity** of the blood is **com-**

paratively slow. It has been ascertained that whilst the blood travels 1 ft., the pulse wave has travelled about 18 ft. The rate at which the blood travels in the blood vessels varies, being greatest in the arteries, very much slower in the veins, and slowest in the capillaries. The dividing up of the stream of blood mainly accounts for this; the veins are far more numerous than the arteries, and the untold subdivisions of the capillary vessels multiply their number enormously. This fact will be readily appreciated when it is realized that it is through the capillaries with their thin walls that nearly the whole of the tissues are irrigated and nourished.

The tissues containing blood vessels are named vascular; certain parts of the tissues are nourished indirectly and do not contain capillaries. The outer skin or epidermis will not bleed if you are careful not to cut below it; the hairs and nails are cut and do not bleed. These must be regarded as dead structures. The enamel forming the crown of the teeth, the cornea of the eye, and some cartilage structures are without capillaries but are nourished indirectly. These are named non-vascular tissues.

CHAPTER XIII

THE BLOOD

The blood is often referred to as the " river of life " to the body, and this is strictly true. The blood courses in many streams laden with nourishment to every part, and returns with waste matters to ports of discharge. To witness the course of these nourishing streams in the midst of the tissues is a sight of great interest and full of instruction. The tail of a tadpole, or the web between the toes of a frog's foot, is thin enough to allow of the circulation of the blood to be seen when placed under the microscope. The red stream swiftly passes along large vessels, the arteries ; next it is seen in fine and almost colourless streams flowing in a network of capillaries, and from these entering larger vessels, the veins. Thus minute streams of liquid nourishment pass intimately into the midst of every tissue. The **thin walls** of the **capillaries permit** some of the liquid portion of the blood, the **plasma**, to pass through, and it literally bathes the tissues. Outside the blood vessels the **plasma** is known as **lymph**, the nature of which is considered in the chapter on Lymphatics.

The blood is **constantly circulating** and **supplying nourishment** to the tissues. **Its composition** therefore must be such as to meet the changing needs of every tissue. The blood is **freely enriched** by substances added to it through the **channels** of the **digestive organs**, whilst on the other hand it continually receives substances which would prove harmful to the body if retained, and these have to be removed and dis-

charged by the **excretory organs.** The blood further is the medium by which **oxygen** is **carried** to **every tissue.**

What is blood? We are familiar with blood as a red liquid that freely circulates in vessels to every part of the body, and if the skin be broken it exudes. When taken from the body we have noticed doubtless that it becomes clotted, forming a red, jelly-like substance. In the case of a cut of the skin, the blood may be seen to form a jelly mass and stop the bleeding. This is Nature's way of arresting the bleeding.

A drop of blood spread out and examined under the microscope shows a large number of rounded-looking bodies,

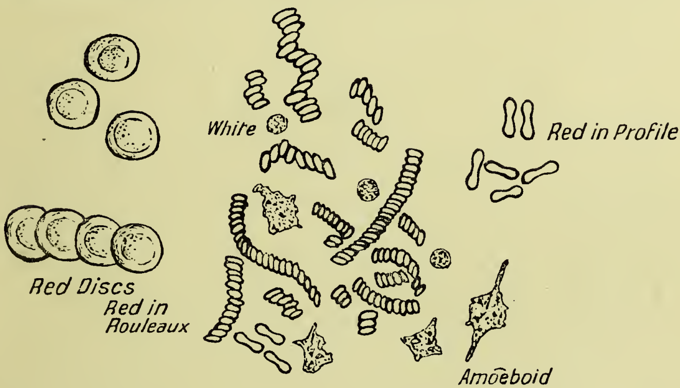


FIG. 39.—Blood corpuscles, red, white and amœboid.

floating in a nearly colourless liquid, the corpuscles and the plasma. In a minute or two after the drop of blood has been drawn from the body and placed under the microscope, the rounded bodies, which are of a **reddish** colour, may be seen to **join** at **their surfaces** and appear in **rolls,** like rolls of coin which have been tipped over, but still in touch. The rolls are also observed to cross, and in the spaces between the rolls are seen a **few globular, granular, colourless corpuscles,** and at times some of these **colourless** corpuscles will be seen to be **irregular.** In this way we note that there are **two kinds** of

blood corpuscles. The **red**, very numerous, and the **white** or **colourless**, which are few in number. On an average there are 500 or 600 red to 1 white. The white increase soon after a meal and decrease in number during fasting.

Red Corpuscles. The human red corpuscle is about $\frac{1}{3200}$th of an inch in diameter. The red corpuscles are of a **protoplasmic nature** surrounded by a **thin, filmy, protective portion**, and they have within them a **colouring** substance containing **iron** combined with another substance, **globulin**, forming **hæmoglobin.** Each minute protoplasmic mass, with its pigment, is in the **form** of a **disc**, with the centre thinner than the surrounding portion. The red corpuscles have a slightly **elastic** character; when they get squeezed in turning the corners of blood vessels their outline becomes altered, but on removal of the pressure the **disc form** is **resumed.** The red corpuscles are not strictly cells, for no nucleus is found present.

White or **colourless corpuscles.** These are **nucleated, protoplasmic bodies** with **few** or **many granules** present. Many of the white corpuscles contain more than one nucleus. When **resting** they often assume a **globular form**, but at other times they are **irregular.** The irregular appearance is due to minute projections, pushed out from the body of the corpuscle. The pushing out of these projections allows the corpuscles to move along **independently** of the blood stream, and even to **crawl through** between the cells of the capillary walls. They **escape from the vessels**, and are found in the **lymph which bathes the tissues.** This special form of movement has been termed **amœboid**, because it resembles that performed by the lowly animal, the Amœba, previously referred to. The white corpuscles can **alter their form** and do it freely at the temperature of the body. They crawl along the sides of the blood stream, whilst the red corpuscles usually travel along the centre.

Examine a drop of frog's blood as well as human blood. In the frog's blood the **irregular character** of the white cells can

be well seen, and in this case the red corpuscles are **large, oval, nucleated cells.**

Plasma is the name given to the **liquid portion** of the blood apart from the corpuscles. It is water, with certain substances held in solution, giving a **pale yellowish fluid** of a slightly **viscid nature.** If blood be drawn from the body and the vessel surrounded with ice, the corpuscles in a short time will begin to sink and leave a pale yellowish plasma at the top.

Plasma is found to contain substances known as **proteids.** All proteids contain the chemical elements, carbon, hydrogen, oxygen, and nitrogen; these are essential, but sulphur and phosphorus are associated with most proteids. The **proteid substances** of plasma are serum-albumin, serum-globulin, and fibrinogen. Plasma also contains **salts** of **soda, potash, lime,** and **magnesia,** as well as traces of **fat, sugar,** and **urea.**

Coagulation. If blood be drawn into a basin, say about half a pint, and allowed to stand for twenty minutes, it sets into a **jelly** or **coagulates.** Soon drops of pale straw-coloured fluid appear, these accumulate, and as the **jelly mass,** now named the **clot,** shrinks, the fluid increases, **being squeezed out of the clot.** The fluid thus obtained is **serum;** it is similar to plasma with this important difference, it contains **no fibrinogen.** When clotting or coagulation of the blood takes place, there are formed a number of very **fine threads** of a substance named **fibrin.** These threads entangle and hold together the corpuscles; at the same time the fibres gradually draw together and squeeze out a pale yellow fluid, serum.

Take a piece of the clot and wash it well under running water until the corpuscles have been washed away, there are left behind some whitish threads of fibrin. These fibres of fibrin have been formed during the coagulation of the blood, and they are **elastic** in character. In the clot they tend to contract and squeeze out the serum. The fibrin fibres do not exist in the blood when it is kept liquid. When **fresh blood** is whipped

with a bunch of twigs, whitish fibres become attached to the twigs; if these are washed and tested, they prove to be fibrin. **After** the **removal** of these **fibrin fibres**, the blood will **not clot.** It can be shown that when blood clots, these fibres are formed from the substance fibrinogen of the plasma, by the action of a **ferment** substance in the **presence** of certain **lime salts.** The ferment is derived probably from the white corpuscles. The substance fibrinogen **is absent** both from the **serum** and from the **clot**, it having been changed into fibrin as explained above.

The **clot** contains all the red corpuscles and most of the colourless corpuscles. If the clot be excluded from the air it becomes dark red in colour, but let it be exposed freely to **air** or **oxygen gas** and it becomes bright red. The **colouring substance, hæmoglobin**, of the red corpuscles has an **affinity** for oxygen; it combines readily with it, and in doing so the clot becomes changed to a **bright red**; if deprived of oxygen it loses its colour and assumes the **dark red.**

The taking up and the giving up of oxygen **readily**, by the hæmoglobin contained in the red corpuscles, make the **red corpuscles** of great value in the **circulating blood.** The hæmoglobin compound is dependent for this **liking for oxygen** by the presence of **iron**; this element, although present in very small quantity, is of the **utmost service** to the well-being of the body. The reduced quantity of iron in the system often shows itself in a pale, unhealthy condition.

Whilst hæmoglobin forms a valuable combination with oxygen, it sometimes forms a very **dangerous one** with **carbon monoxide.** This combination is a **firm one**, which **prevents** the hæmoglobin taking up **oxygen**, and highly poisonous effects follow.

"Blood is thicker than water," i.e., it is heavier than water; let a drop of blood fall into water and it sinks. The **density** or **weight** of blood compared with water is its S.G. or **Specific Gravity.** If water be taken as 1000, then blood varies between

1055 and 1060 at 60° F. Blood is **water** plus certain substances in solution, and containing **bodies** or **corpuscles.** Its composition must vary, because it is **continually** taking up and giving up substances, but in order to **maintain** a condition of health it is only possible for the blood to vary within **very narrow limits.** Like the maintenance of a constant temperature by a remarkable balancing of functions, so in the case of the composition of the blood it is **well regulated** under **normal conditions** of the body.

Water plays an important part in all the functions of the body. The fluids of the body are chiefly water. In the case of the blood there is about **79 per cent of water** and **21 per cent of solids.** In the **plasma** is found about 90 per cent, and in the **corpuscles** about 67 per cent, of **water.**

The **mineral salts** dissolved in the blood are small in quantity but very important. There is a remarkable capacity on the part of the blood to **take up mineral substances,** as well as other things as required, according to the demands of the body. Think of what happens when hard structures such as bones are being formed. The **demand** for **mineral salts is great,** and the blood is ready to meet with it, and the same is found in other cases of special requirements of the body.

CHAPTER XIV

RESPIRATION

The function of **Respiration** or breathing consists of Inspiration and Expiration, the passage of air into and the passage of air out of the lungs. From the first inspiration taken at birth, expiration has followed on inspiration, and under **normal conditions** without the slightest effort on our part. **Asleep** or **awake** the mechanism of respiration goes on with perfect regularity. That it should proceed without any effort on our part at once shows it to be an **involuntary act**, i.e., independent of our will. We just as readily, however, realize it to be **subject to control** when **we modify it** in speaking and singing. The **essential object** served by respiration is to take in air, to supply oxygen gas to the blood, and at the same time to receive from the blood, as it courses through the capillaries of the lungs, waste products, carbon-dioxide gas chiefly, but also water vapour and organic matter. To this end, the breathing organs, the lungs, communicate with the external air by way of the nose and mouth. The **nose** is the proper inlet for air to the lungs, whilst the mouth is more concerned in the passage of food to the stomach. To understand this important function of breathing we must carefully consider and examine the parts concerned in its mechanism, the Thorax and Lungs.

The **Thorax**, forming the upper division of the trunk, commonly spoken of as the chest, is separated from the abdomen by an arched partition, **composed** of **muscle** and **tendon**, and named the **diaphragm.** The examination of the thoracic

cavity in a rabbit will show the interior to be smooth, due to a lining of membrane, part of the **pleura** ; the cavity itself is cone-shaped, the broad base is formed by the diaphragm. Upon this rests the concave, lower portions of two pink, spongy masses, the **lungs** ; these in the distended state fill most of the cone-shaped thorax, the heart occupying a space about midway between the two lungs. The lungs are rendered perfectly smooth outside by a layer of the pleura, and when inflated this surface is in contact with the layer of the pleura that lines the cavity of the thorax. The **Pleura**, then, is a thin connective tissue membrane of two layers, kept in contact and moistened by a **serous fluid** to allow of smooth working of the lungs.

The **thoracic cavity** is bounded by the twelve dorsal vertebræ at the back ; and at the sides and front by the twelve pairs of ribs and sternum. The ribs sweep round from the vertebræ, **seven** pairs become **joined directly** and **three** pairs **indirectly** to the **sternum** in front, two pairs—eleventh and twelfth—are floating, that is, having no connexion in front. Note the position of the ribs is downwards and forwards, and they become joined to the sternum by **costal** or **rib cartilages** which bend sharply upwards from their junctions with the ribs to meet and join the sternum. The curving of the ribs from the vertebræ and their upward junction with the sternum allows the cavity of the thorax to be deeper at the back than at the front, and the lungs are correspondingly shorter in front than behind. The bony and cartilaginous framework of the thorax is thus arranged.

Next, the muscular structures must be noted. Filling in between the successive pairs of ribs are seen red muscles, named the **intercostals** ; there are two layers—one layer, the **external intercostals**—the fibres of which run from the rib above to the rib below, downwards and forwards ; the other set —the **internal intercostals**—run from the rib above to the rib below, downwards and backwards. Outside these structures, bony and muscular, are the large muscles of the breast and

back, and covering the whole, the skin. The upper narrow portion of the thorax is closed in by the muscles of the neck, the windpipe, and great blood vessels, whilst the floor is formed by the diaphragm.

The **diaphragm** is an important structure in breathing. It forms a dome or convex portion above, and below a hollow, concave portion. It has a **strong, tendinous** attachment to the back-bone. The strong fibres arising partly from the lumbar vertebræ spread out into a central portion, from which a **red muscular** portion radiates to become connected with the lower ribs and their cartilages and the lower end of the sternum. When this **muscular, tendinous diaphragm contracts,** the floor of the thorax is lowered and the space from top to bottom is increased.

At the same time at which this takes place, the **external intercostal muscles** contract and raise the ribs from a **sloping position to the horizontal position,** and in doing so **slightly thrust forward the breast-bone** to which they are attached in front. The distance from **front** to **back** is **increased,** and, moreover, by virtue of the curved nature of the ribs, there is also an **increase** of **space** from **side** to **side.** Thus the thorax is enlarged from front to back, side to side, and top to bottom, and in **inspiration the lungs follow this enlargement of the cavity.**

Observe closely the structures and arrangement of the parts in the thorax of a rabbit from which the organs have been removed by cutting away one side of the chest wall whilst leaving the sternum and diaphragm intact. Draw down the sternum slightly, then press upward a little and note the enlargement of the cavity.

Supplement this observation by placing your arms in a sloping position with the tips of the fingers touching, and slowly raise the arms to the horizontal position. In doing so, let the fingers, which represent the sternum, go outward slightly and allow the elbows to bow out to represent the curves of the ribs.

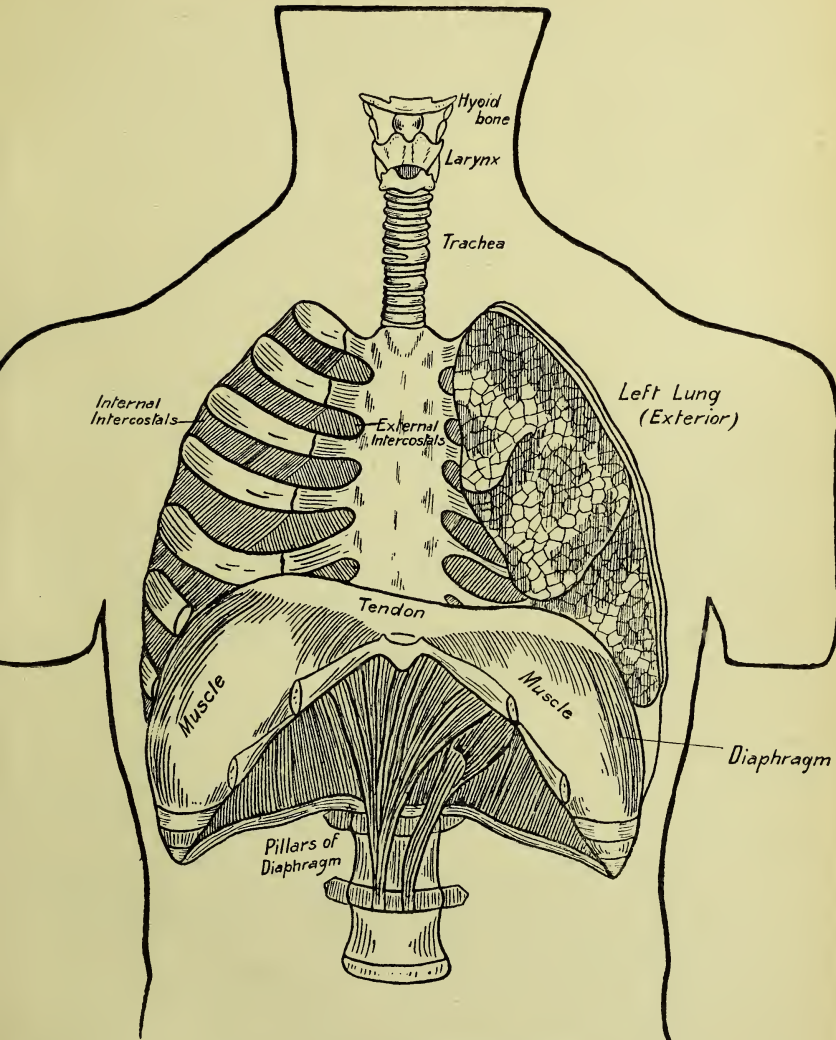


FIG. 40.—Thorax and diaphragm.

It will now be noted that the space between the arms and the body has been increased from side to side and from front to back. This experiment will roughly illustrate what follows in relation to the thorax when the ribs are raised. It must be kept in mind, however, that the first rib is practically fixed, and the contraction of the external intercostal muscles has the tendency to bring each successive rib near the one above, and the whole effect is to increase the space as already described.

Lungs. An examination of the lungs should be made next. Procure the entire lungs of a sheep, with the windpipe and larynx or throttle attached. The whole mass is light in weight, readily floats in water, spongy and elastic to the touch. Pinkish in colour, smooth, the front short and thin at the border, the back long and thick. The right lung has three divisions, lobes, the left two lobes ; a slight subdivision likely will be seen as well. The surface of the lungs has a mottled appearance, little areas marked by fine lines between them ; these areas indicate subdivisions known as lobules.

Next examine the **larynx** at the upper end of the windpipe. Note the broad shield piece of cartilage, thyroid ; this is felt at the front of the throat, and is known as Adam's apple. It is imperfect behind and embraces another cartilage, cricoid. These two cartilages form the front, back, and sides of the larynx. Look into this enclosure at the top and see a V-shaped opening, the **glottis,** bounded by the **vocal cords.** Above the opening is a leaf-like piece of cartilage, the **epiglottis,** very free and flexible ; press it down and it closes over the glottis.

The **Windpipe** or **trachea** is made up of a number of hoops or rings of cartilage, incomplete behind, against which a muscular tube, the gullet, lies. The rings are joined to one another by muscular and other tissue, and similar structures unite the ends of the rings at the back. **Inside** the tube is lined by a membrane, **mucous membrane,** smooth and moist and thrown into slight ridges. The whole tube is kept **freely**

open by the rings of cartilage and at the same time is **flexible.** At the lower end the long windpipe divides into two, the **bronchi,** and these freely subdivide into numerous smaller branches. To follow this, slit open one side of the lung following the main tube (bronchus). It is similar in structure to the windpipe; the cartilages, however, are now in small pieces, not rings, but serve the same purpose, namely, **to keep**

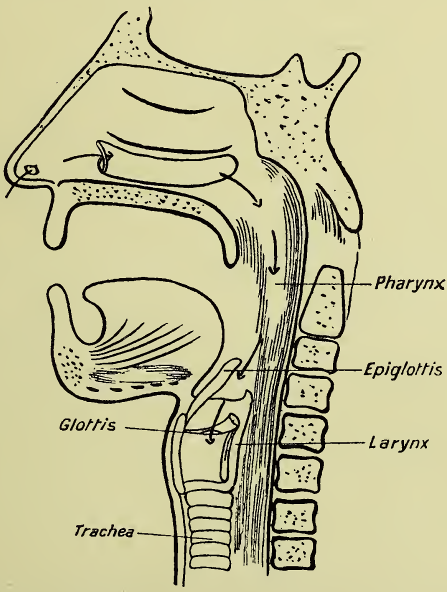


FIG. 41.—Diagram showing passage of air to the lungs.

open the passages. The tube has **frequent outlets** into smaller tubes as it runs through the spongy mass.

Next cut across a portion of the same lung and carefully examine the cut surface. The spongy nature of the lung is very evident. Running through the pinkish, spongy mass are certain tubes of various sizes. Some of the openings have **cartilage** in their walls; these are the smaller branches of the

bronchus, the **bronchial tubes.** Other openings have **no cartilage** present ; these are **small arteries ;** they are stout enough in their walls to stand open when cut across. Draw apart the spongy mass and other openings appear, but their walls readily come together ; these are **small veins.** Squeeze the mass ; minute drops of blood are seen here and there, probably coming from capillary vessels. Thus the chief structures are brought to view, but the **spongy nature** of the lungs is due to **myriads of microscopical air-sacs.**

Picture at the ends of all the **finest bronchial tubes** very small, **pear-shaped, elastic bags,** and **these again crowded with very numerous air spaces,** so minute that it is estimated that over seven hundred millions of these air-sacs are packed within the area of the human lungs. Then on the outside of these millions of extremely minute air-sacs, with their walls of the thinnest possible elastic tissue, are **spread** in **close networks** the **thin-walled, capillary blood vessels.** The blood as it courses along the network of capillaries is separated from the air contained in the air-sacs by the very thin walls of the vessels and the air-sacs.

If the student, in addition to following the structure of a sheep's lung, will examine the lung of a toad or frog immediately after death, the arrangement of the air-sacs and blood vessels on their walls will be readily understood. The whole lung of the toad or frog practically represents one of the divisions at the end of a bronchial tube in the human lung.

RESPIRATORY PASSAGES. The air entering the human lungs enters either by the nose or mouth. By way of the **nose** is undoubtedly the **proper channel** for the air ; ample **provision** being made for **warming** and **filtering** the air **before** it enters the lungs. Projecting into the nasal cavities are thin plates of bone, rolled up like scrolls, the turbinated bones. These, and likewise the cavities, are covered by a thick, moist, warm mucous membrane ; thus the air in passing over the membrane is warmed and the dust particles are caught by the moisture.

The air entering by the **anterior nasal** openings passes along the **lower chambers** of the nasal cavities and out at the **posterior openings** into the **pharynx.** The **pharynx** is the upper part of the gullet, the enlarged end of a muscular tube; it is attached to the base of the skull and is open in front for the reception of air from the posterior nasal openings and food from the back of the mouth. The pharynx is continued as the gullet which runs down behind the windpipe to join the stomach. The pharynx is the common channel for food and air. The air is drawn in at the top of the larynx through the glottis into the trachea. These passages are kept free for air, whilst the passage by way of the gullet is closed by the contraction of the muscular walls, except when food is passing (Figs. 41-50).

The **human Trachea** is about 4 in. in length and nearly 1 in. in width. It is surmounted by the larynx, and this is attached to the back or root of the tongue by the hyoid bone and by muscles. The trachea is made up of from sixteen to eighteen **cartilaginous rings,** incomplete behind, joined together at the back to one another by plain muscle fibres and **lined internally** with **mucous membrane**—a soft, moist, reddish membrane containing numerous mucous glands, and covered by **ciliated epithelial cells.** The **cilia,** fine hair-like processes of the cells, are **active in driving the mucous secretion outwards,** precluding it from settling down into the air-sacs and interfering with breathing. The trachea, after passing along the front of the neck, forks in the thorax just inside the top of the sternum, the **right** and **left bronchi**; and as one passes to each lung it branches and subdivides into **bronchial tubes,** and when the smallest are reached, these end in **bags** of **air-sacs** as described above. All the passages are kept free to the passage of air by the presence of small pieces of cartilage, and the whole are lined with mucous membrane having ciliated epithelial cells.

The right human lung has three lobes, the left two. They form two cone-shaped, spongy masses, and are composed of

bronchial tubes which terminate in dilated, membranous bags. The bags are crowded with minute air-sacs of elastic tissue. The pulmonary artery enters the lungs and branches freely. Capillaries arise from these and cover the walls of the air-sacs ; from these, veins arise and return the blood to the heart. In addition to these structures numerous lymphatic vessels and nerves are found.

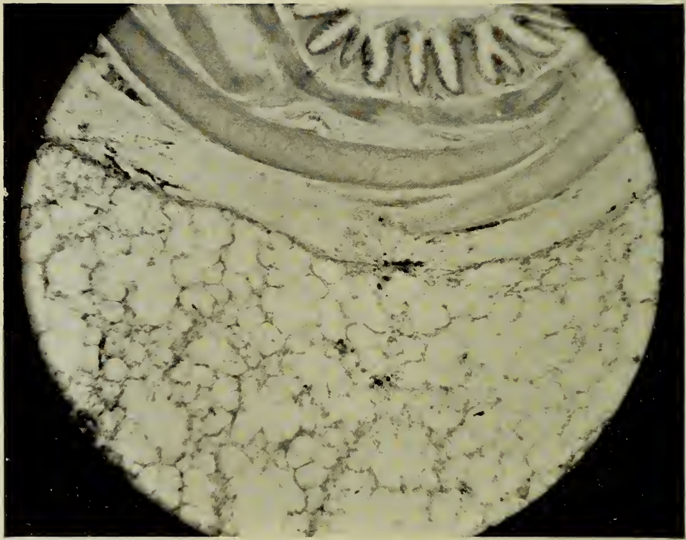


FIG. 42.—SECTION OF HUMAN LUNG SHOWING BRONCHIAL TUBES AND AIR-SACS. PHOTOMICROGRAPH

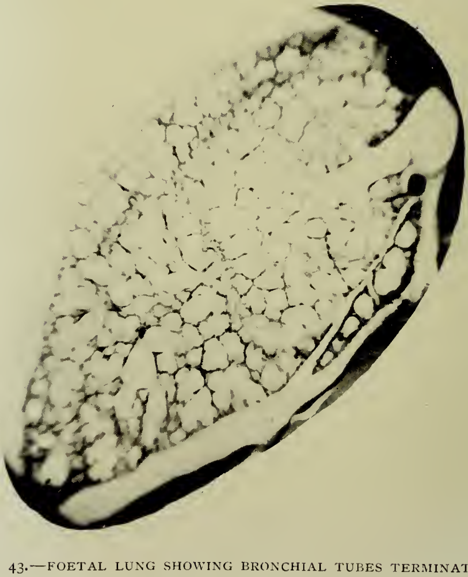


FIG. 43.—FOETAL LUNG SHOWING BRONCHIAL TUBES TERMINATING IN AIR-SACS. PHOTOMICROGRAPH

CHAPTER XV

RESPIRATION (*Continued*)

THE LUNGS AND THORAX IN ACTION. The lungs are contained in an **air-tight cavity**, the **thorax**, which (together with the heart) they fill, and when the thorax enlarges by the raising of the ribs, the pushing of the sternum slightly outward, and the lowering of the floor by the contraction of the diaphragm, the lungs **further distend** and **continue to fill** the **cavity** of the **thorax**. It is the **air within the lungs** which keeps them distended, and as more air passes in they distend still further to fill the increased space provided. The lungs easily distend, because they are in an air-tight chamber and there is nothing to counteract the pressure within. This pressure is due to a long column of atmospheric air pressing down through all the air tubes. The elastic tissue of the lungs has been put on the stretch, and as soon as the tension is reduced they recoil. This takes place to bring the lungs back to a size sufficient to occupy the reduced cavity, because immediately after enlargement the ribs and sternum come down and the diaphragm goes up by the muscles ceasing to contract. The effect of these changes is to allow a certain amount of air to pass into the lungs; that is **Inspiration**, and to press a certain quantity of air out of the lungs, **Expiration**.

Respiratory movements take place some fifteen to eighteen times per minute in quiet breathing. Quick walking or running will greatly increase the number. As you sit quietly count the number of respirations you make in one minute, and observe

exactly what follows during inspiration and expiration. By your observations verify the statement that the ribs, sternum, and diaphragm all change their positions. Note also that in **males** the **diaphragm** has freer action than the upper part of the chest. In **females** the **chest action** is greater, the diaphgram has less action, and abdominal respiration, as it is named, is restricted. **Perfectly free movement** of both the ribs and the diaphragm is **highly important** in **proper breathing** and **tends largely to health** and **strength of body.**

CAPACITY OF THE LUNGS. **Capacity** of the adult lungs is about 230 cub. in. Under ordinary conditions there are found in the lungs about 200 cub. in. of air, named **Stationary** air, which fill the lungs up to about the level of the bronchi. **At each breath** some 25 to 30 cub. in. of air, Tidal air, flow in and out. In a man well exercised in breathing it is possible for him to force out of his lungs after the expiration of the tidal air, 30 cub. in., another 100 cub. in., leaving in the lungs 100 cub. in., named **Residual** air. This latter resists expulsion, due to the fact that it is contained in the myriads of minute air-sacs. Again, such a man may be able to take in another 100 cub. in. on the top of the 230 cub. in. by a very powerful inspiration, making 330 the **absolute total.** You will, however, remember that there is passing in at each inspiration about 30 cub. in. and a similar quantity passes out at each expiration. This **tidal air** in passing into the lungs gets only as far as to meet with the so-called **stationary air,** and **here important changes** take place in its composition.

INSPIRED AND EXPIRED AIR. The composition of fresh atmospheric air may be taken to be :—

Nitrogen . .	79	per cent.
Oxygen . .	20·96	„
Carbon dioxide	0·04	„

with some water vapour which varies according to temperature.

After such air has passed into the lungs and has been breathed out again, certain changes are easily shown to have

taken place in its composition. It has increased in temperature, we can feel the warm breath; it contains so much water vapour that this at once condenses if the breath is brought in contact with a cool surface, such as a sheet of glass or when it meets with cold air. Further, if the expired air be led through a glass tube into a clear solution of lime-water, the solution quickly becomes turbid or milky, which is due to the formation of carbonate of lime by the union of the carbon-dioxide gas with the lime of the lime-water. The presence of organic matter in expired air can be also shown by passing the breath into a very pale rose-coloured solution of permanganate of potash for several minutes; change in colour of the solution will take place.

Next test fresh air in a similar manner. Compared with expired air as a rule it is not so warm; it does not easily show the presence of water vapour; if led into lime-water the carbon dioxide is insufficient to cause turbidity; it will not cause a solution of permanganate of potash to change colour. The composition of expired air may be taken to be:—

Nitrogen . .	79	per cent.
Oxygen . .	16	,,
Carbon dioxide	4	,,

Compared with inspired air it shows a loss of about 5 per cent of oxygen, and the carbon dioxide has increased to 4 per cent. Most of the oxygen taken in unites with carbon to form carbon dioxide, but some of it unites with hydrogen to form water in the body.

THE CHANGES BETWEEN THE AIR AND THE BLOOD. The **changes** taking place in the **air** in passing in and out of the lungs are obviously effected through the stationary air. This gives to the expired air some carbon-dioxide gas, water vapour, some heat, and traces of organic matter, whilst the **inspired** air parts with **oxygen.** But the exchange is really between the air in the air-sacs and the blood in the capillaries outside the air-sacs. The walls separating the air and the blood

are **very thin**, and oxygen gas from the air-sacs **diffuses through** and is taken into the blood, whilst the carbon-dioxide gas, and the water vapour, and other things **escape from the blood** into the **air-sacs**, and these are passed out with the next breath.

It is necessary to note the changes that have happened to the blood in passing through the capillaries of the lungs. **When the blood leaves the right side of the heart it is dark in colour or venous, and when it arrives at the left side of the heart it is bright scarlet or arterial.** In seeking the cause of this change of colour, we find that if **dark** or venous blood be **exposed** to the **air** for a short time, or better, if a **stream of oxygen** be played on some venous blood when spread out in a thin layer on a white dish, the **colour quickly changes** to bright scarlet like arterial blood. We see that either air which contains oxygen or oxygen gas direct can effect the change in blood from dark to bright colour. It is also evident, from what has been already considered, that blood in passing through the capillaries of the lungs becomes exposed to the oxygen of the air which is breathed into the lungs and which we now conclude changes the colour. **Venous blood** leaving the **right** side of the heart **is changed** in **colour during its passage through the lungs** and arrives at the **left auricle as scarlet or arterial blood.** On the other hand, the blood leaves the left side of the heart as bright coloured arterial, **passes through** the **systemic circulation**, and arrives back to the right side as **dark-coloured** or **venous blood.** This **change** of **colour** must have taken place **during its passage through the tissues** of the body. We must now remember that all **living and active tissues demand oxygen**, it is **essential** to **their activity**, they are **hungry for it.** As the blood stream brings round the supply of oxygen from the lungs, it is given up to the tissues along with the plasma of the blood. **The giving up of oxygen causes the blood to lose its bright arterial character** and to **become dark** or **venous.**

How does the blood hold the oxygen? It is found that the oxygen gas is absorbed by the blood, and held **chemically** by the **colouring matter,** hæmoglobin of the red corpuscles. As the corpuscles pass along the capillaries of the lungs, the **hæmoglobin** readily **absorbs** the oxygen from the air of the air-sacs, and the blood becomes scarlet; and in passing through the tissues, the **hæmoglobin gives up some** of the oxygen to the tissue, and the colour becomes darker. In a brief time the corpuscles are again floating along the stream of

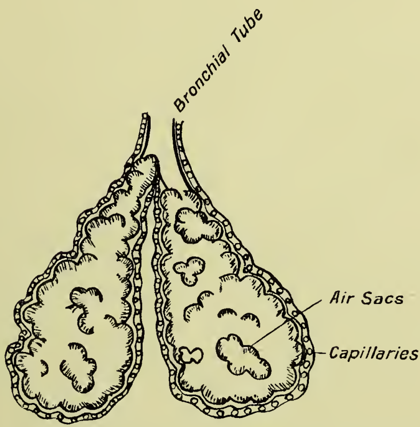


FIG. 44.—Two infundibulæ with capillaries—diagrammatic.

blood in the capillaries of the lungs, where they become recharged with oxygen and fitted for another journey. If we put something into arterial blood to take up some of its oxygen a change of colour ensues; it is said to be reduced. So with the blood circulating, **its hæmoglobin gets reduced,** by losing some of its oxygen to the tissues. The **obvious difference** between arterial and venous blood is **one of colour.** Arterial is bright scarlet in colour because the hæmoglobin is fully charged with oxygen. Venous blood is dark red in colour because the hæmoglobin of the red corpuscles has lost some

oxygen and become reduced. There are, however, other differences between venous and arterial blood to be explained.

All liquids absorb gases to which they are exposed, and blood contains the gases oxygen, carbon dioxide, and nitrogen. It is found that venous blood contains relatively more carbon dioxide and less oxygen than arterial blood. As the blood passes along the tissues, it not only **gives up oxygen but it takes up carbon** dioxide and when the blood gets back to the lungs the **carbon dioxide** is excreted as we have seen in the expired air. The blood also gives up **water vapour, heat,** and a **little organic matter,** as excretory products, to expired air. In this way it becomes purified, and at the same time becomes charged with a supply of oxygen for the tissues. The carbon dioxide taken up by the blood from the tissues is **partly absorbed** into the liquid and **partly held** by certain constituents in the blood in chemical combination.

The act of breathing, then, means the inhaling of a given quantity of air into the lungs and its expulsion from the lungs. The indrawn air first diffuses with the air already there, and then some of its oxygen diffuses through the walls of the air-sacs into the capillaries. The oxygen is absorbed by the hæmoglobin of the red corpuscles and carried to the tissues of the body. The tissues being hungry for oxygen withdraw some of it, reduce it, and the blood changes in colour as a consequence. At the same time the blood in circulating through the tissues absorbs the carbon dioxide and other waste substances, resulting from the work of the tissues. These are carried back and some of the waste excreted by the lungs. Nearly the whole of the carbon dioxide produced in the body is taken to the lungs to be expired with the outgoing air.

CHAPTER XVI

ORGANS OF DIGESTION

The **preparation** of the food to be absorbed and assimilated in the body involves a consideration of the structures of the alimentary canal and its accessary glands. The **alimentary** or **food canal** includes the **mouth, pharynx, gullet, stomach, small** and **large intestine,** and **anus.**

The **mouth entrance** to the alimentary canal is bounded by the muscular lips and cheeks, and within these are the bony jaws holding the teeth. The **front part** of the roof of the mouth is bone covered by membrane, the **hard palate** ; beyond this is the soft palate. The entrance to the pharynx, the fauces, forms an archway from the roof which is the **uvula,** and at the sides the **tonsils** are situated. The **tonsils** are of loose, spongy tissue ; they give out a slimy secretion which helps to lubricate the food in passing to the pharynx. The floor of the mouth is formed by the **muscular tongue,** and beneath this are certain glands and muscles. Under the tip of the tongue is a thin membrane, the **frenum.** This membrane in early life sometimes ties the tongue and has to be cut. The muscular character of the tongue enables it to move the food about in the mouth, and by pressing the food against the palate to express flavours, and finally it carries the bolus of food to the entrance of the pharynx.

The mouth cavity is lined by a soft, moist, red membrane, named mucous membrane. It is not a true mucous membrane but a skin membrane. The first part of the alimentary canal at each end has the lining membrane formed of cells in layers

just like the skin. This condition is found not only in the mouth but extends as far as the pharynx and gullet. In the lining membrane of the mouth are found numerous little glands which secrete a thickish fluid; this, together with the saliva, keeps the mouth moist.

GLANDS. A gland is essentially an arrangement of secreting cells in relation to blood vessels. The **cells** are the **active agents**, taking from the blood brought to them by the blood

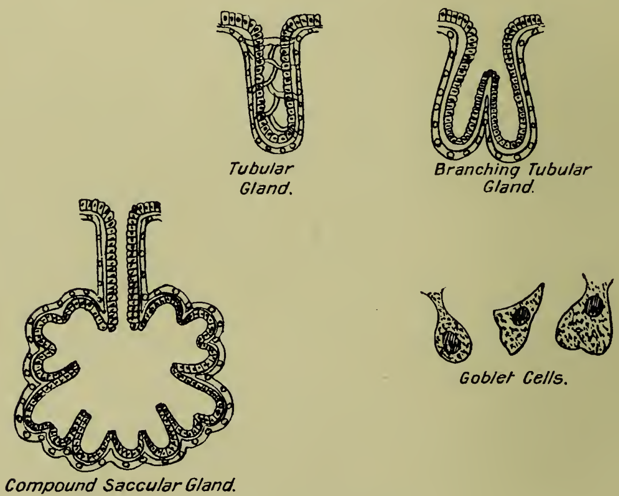


FIG. 45.—Types of glands.

vessels the materials to form a secretion. The secretion is of use in the body, and the gland producing it is named a **secretory gland.**

In the **mucous membrane** lining the alimentary canal numerous glands are found, namely, **mucous, gastric,** and **tubular glands.** There are other glands, the salivary, the liver, and the pancreas, which **open by ducts into the alimentary canal** and provide secretions used in the digestion of the food.

The **Salivary glands** are three pairs, named the **Parotid**, the **Submaxillary**, and the **Sublingual**. Each **parotid** is situated in front and below the ear, between the skin and muscles. A duct leads from it into the mouth and opens near the second molar tooth of the upper jaw. The **submaxillary** glands are situated below and just within the border of the lower jaw, one on each side of the jaw. Ducts from these glands open under the tongue, and quite near these are openings from the third pair, the **sublingual** glands, situated below the tip of the tongue in the floor of the mouth. Drops of saliva

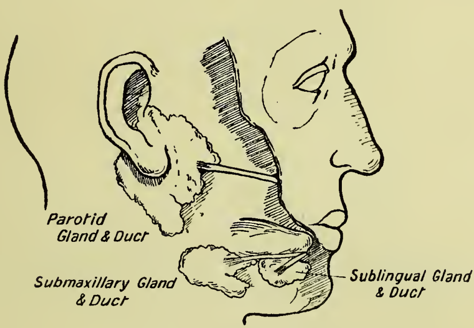


Fig. 46.—Salivary glands in situ.

may be seen coming out of these ducts by suddenly lifting the tip of the tongue.

The **Salivary glands** are irregular, soft-looking masses composed of small divisions, lobes, held loosely together by connective tissue. Each lobe is a mass of **smaller lobes**, and these are composed of **secreting cells** arranged to surround little spaces. The spaces open into fine channels or ducts, and finally the main duct is formed and opens into the mouth. **Blood vessels** ramify in the midst of the cells and from the blood supply the cells form saliva.

The **quantity** of **saliva** secreted daily by these glands is about two pints. A thin, watery fluid is secreted by the parotid

glands and a thicker secretion from the submaxillary and sublingual glands ; the thicker character is due to the presence of a mucus. **Saliva** has about **0·5 per cent of solids** and **99·5 per cent of water.** The small quantity of solids contains a **very important substance, Ptyalin,** of the nature of a **ferment.** This **ferment** possesses the property of changing starch into a kind of sugar. Saliva is **alkaline** in reaction ; test it with red litmus paper. **Its action** on **cooked starch**

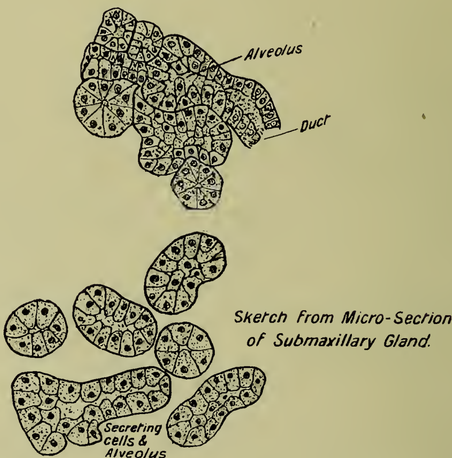


FIG. 47.—Sketch of cells o! micro-section of submaxillary gland.

in the mouth is **rapid,** and this fact can be easily shown by the following simple experiments :—

Take some starch and make it into a thin paste with cold water. Add a little of this to some boiling water to form a weak starch mucilage.

Experiment 1. Place a small quantity of the starch mucilage in a test-tube and add a drop or two of Iodine solution. Reaction, a blue colour, which disappears upon heating and reappears upon cooling. This is the test applied for starch.

Experiment 2. Take a small quantity of bread, boiled potato, rice or peas, and shake up with water. Filter and test the solution for starch.

Experiment 3. Take a little of the starch mucilage into the mouth ; hold it there for a minute or two, then run it into a test-tube, dilute it with a little water and apply the starch test. No blue reaction.

Experiment 4. Place a few drops of starch mucilage

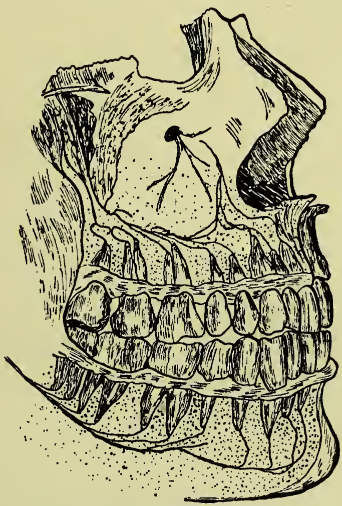


FIG. 48.—View of upper and lower jaws showing teeth in position and nerve supply.

in a test-tube, keep it warm and run in a little saliva from the mouth. Apply starch test. No reaction.

Experiment 5. Repeat this experiment, using **saliva** that has been **boiled.** Apply the starch test. Blue reaction.

From the above experiments four facts are demonstrated :—

(*a*) The **presence** or the **absence** of **starch** in the solutions.

(*b*) The **change wrought** on **cooked starch** in the presence of saliva in the mouth.

(*c*) The **short time** taken by the saliva to effect this conversion.

(*d*) That the **active agent** of saliva is **killed** by **boiling.**

We must next endeavour to show the nature of the substance brought about by the action of saliva on starch.

Experiment 6. Place some starch mucilage in the mouth, mix it with the saliva for a minute or two and then run it into a clean test-tube. Divide this into two portions and **test one** for **starch.** To the other portion add a drop or two of dilute copper sulphate solution, then a few drops of sodium or potassium hydrate. Next heat the solution in a

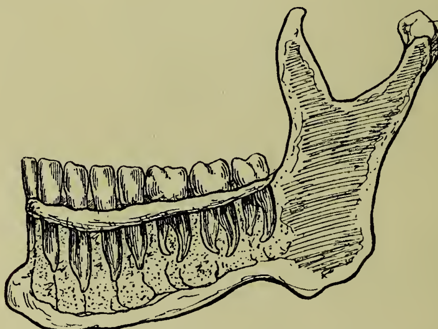


FIG. 49.—View of lower jaw showing teeth in sockets.

Bunsen or spirit flame—a brick-red precipitate is formed. This is the test applied for sugars of which grape sugar is a type.

Experiment 7. Shake up a **bruised raisin** or **grape** with a little warm water and test the solution for sugar.

Experiment 8. Chew a small piece of starchy food and place the mass in a tube, shake it up with warm water, strain off and apply the sugar test to the liquid. Result—evidence of sugar.

These experiments with saliva show the **chemical change** in **starchy foods brought about** in **mouth digestion. Saliva** also helps to **soften food,** and this **softening** is aided by the

function of mastication in breaking up the food, and in these conditions the food is rendered fit for swallowing.

THE TEETH. The teeth in the upper and lower jaws are in sockets and firmly held by the periosteum lining. It is this membrane that bleeds freely by rupture of its blood vessels when a tooth is extracted. The gum marks the neck of a tooth ; the part above is the crown ; the portion below the neck, and

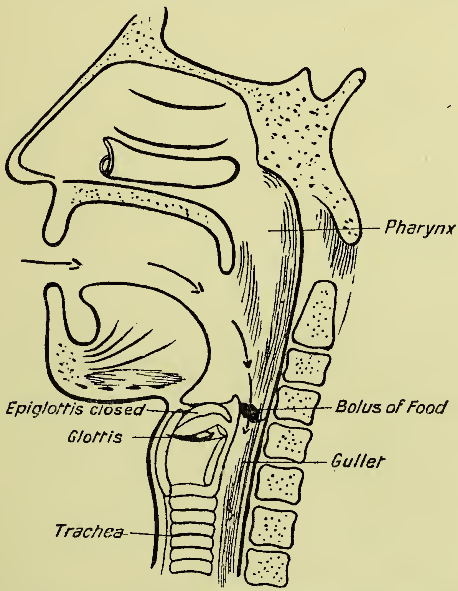


FIG. 50.—Diagram to show the passage of food from the mouth into the gullet and the closure of the epiglottis.

buried in the socket, is the fang or root, which may be simple or divided.

The crown of the tooth has an external coating of enamel, the hardest substance in the body, made up of about 97 per cent of mineral salts. The root has an external coating of a bone-like structure named cementum. The bulk of the tooth consists of another bony tissue, the dentine ; this sub-

stance is similar to ivory as found in the tusk-teeth of certain animals. At the **apex** of each fang is a small hole, which **allows** of the **entrance** of some **fine nerves** and **blood vessels** into the **pulp cavity.**

Kinds of Teeth. **Incisors,** in front of the jaws with **chisel-like edges.** **Canines,** on each side with **pointed crowns;** on each side of these are the **Bicuspids** or **pre-molars,** and beyond these the **Molars.** **Both** the bicuspids and molars have **broad, irregular, grinding surfaces.** The teeth are adapted in relation to mastication of the food, to **cutting, tearing,** and **grinding.** The **lateral motion,** as well as the **vertical action,** of the lower jaw provides for perfect mastication.

The number of teeth in the **permanent** set of thirty-two are graphically given by initial letters as follows :—

Upper : MMM BB C IIII C BB MMM
Lower : MMM BB C IIII C BB MMM

Preceding the permanent teeth a set of **twenty temporary teeth** appear between the ages of six months and two years, made up of :—

Upper : MM C IIII C MM
Lower : MM C IIII C MM

About the 6th year the temporary teeth begin to be replaced by the permanent set ; and by the 14th year these have erupted, except the four wisdom teeth, which may appear between the 17th and 25th year or later.

Perfect nutrition during early life, proper care, and daily attention to the hygiene of the teeth subsequently, are conditions necessary to secure and preserve strong, sound teeth. The function of mastication performed by good teeth, properly carried on, cannot be overestimated in relation to the complete digestion and assimilation of our food.

CHAPTER XVII

ORGANS OF DIGESTION (*Continued*)

THE PHARYNX AND GULLET. From the mouth the food passes by way of the fauces or opening at the back into the next portion of the alimentary canal. This is a tubular passage with muscular walls extending from the base of the skull along the neck and thorax between the vertebral column and the windpipe ; it passes through the diaphragm and opens into the stomach near the large end. The upper 4½ in. of this muscular funnel is the **Pharynx** and the lower 9 in. is the **Gullet** or **œsophagus.** The passage is lined throughout by a smooth, moist membrane of many layers of cells and containing numerous mucous glands.

The **Pharynx** receives both **air** and **food.** The air from the nasal passages goes by way of the pharynx into the trachea through the glottis, whilst **the food is passed down the gullet by a series of muscular contractions.** The food escapes passing into the glottis, except occasionally when a " bit goes the wrong way," because at the moment of swallowing the **larynx** is **slightly raised** against the base of the tongue, the **epiglottis closes** over the **glottis,** and the food passes over the **epiglottis** into the **gullet** (Fig. 50).

Stomach. The narrow gullet opens into the most dilated portion of the alimentary canal, the stomach—an irregular, pear-shaped bag, reaching across from the left towards the right side of the abdomen. Its exact position depends upon its condition of fullness or otherwise. When moderately full it has a capacity of nearly two quarts. The **left** or **cardiac**

end is **wide** and from the upper side is supported by the gullet as it passes through the diaphragm. The **narrow end** of the stomach is on the **right side** and is named the **Pylorus.** The walls of the stomach are formed chiefly of plain or involuntary muscle, and the muscular layers are arranged lengthwise, circularly, and some obliquely. **By this arrangement of muscular tissue** the contents of the stomach become compressed and well mixed with the secretions of the stomach. The **circular muscular fibres** become much thickened at the **pyloric end** to form a **sphincter muscle,** which prevents the food passing until it is in a **semi-fluid condition.** The sphincter muscle relaxes very little and the food is squeezed through a **small aperture** into the duodenum. **Another sphincter muscle** is found at the junction of the gullet and stomach ; this has to be forced open in case of vomiting. **Outside** the muscular coats of the stomach is a smooth covering of **serous membrane. Mucous membrane** lines the **inside** of the muscular structure. This important layer consists of two parts, the **submucous** and **mucous,** this latter forms a soft, velvet-like layer over the surface. In the mucous membrane of the stomach there are **simple** or **branched, tubular, gastric glands.** The cells at the mouths of the glands are **columnar,** but lower down they become **cubical,** and these are the **secreting cells ;** in some of the glands **ovoid cells** are found. Running up between all these glands from the submucous layer are numerous capillary blood vessels and nerves. **Owing** to the **loose attachment** of the lining of the stomach, the layer becomes thrown into **folds** when the organ is empty. The examination of the stomach of a rabbit will make clear most of these structures.

Gastric Juice is the name given to the **acid secretion** of the stomach. The secreting cells of the numerous glands in the mucous coat take from the blood the materials which they convert into an acid fluid, and this **gastric juice** contains about **0·5 per cent of solids** and **99·5 per cent of water.**

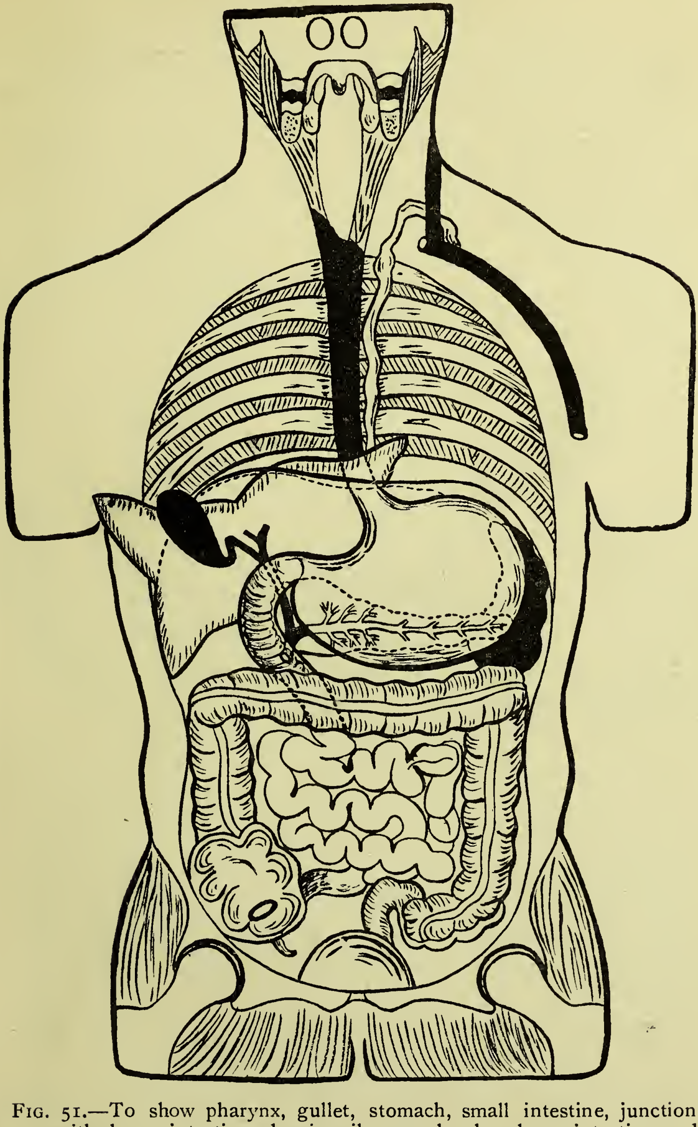


Fig. 51.—To show pharynx, gullet, stomach, small intestine, junction with large intestine showing ileo-cæcal valve, large intestine and opening of bile and pancreatic ducts into the duodenum. Thoracic duct also shown.

It has, however, two important constituents, a **ferment** named **Pepsin**, and a mineral acid, **Hydrochloric.** It also contains a milk-curdling ferment, **Rennin.**

When **proteid substances** such as **albumen, casein, gluten,** and others enter the stomach and become mixed by the muscular action of the stomach with the gastric secretion, the ferment pepsin, together with the hydrochloric acid, **digests** them, that is, makes them **soluble** and **diffusible.** In this condition **some** of the food will become **absorbed** into the blood vessels of the stomach.

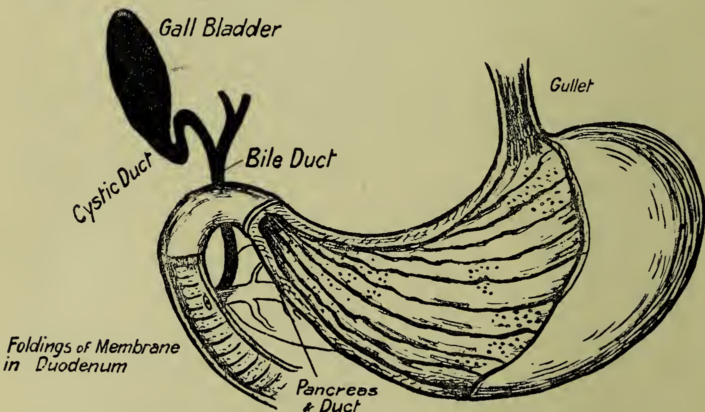


FIG. 52.—Stomach and duodenum showing coats, gall bladder, bile and pancreatic ducts opening into the duodenum.

The Small Intestine. From the **pyloric end** of the stomach begins the small intestine, a tube from 20 to 22 ft. in length, and of nearly equal diameter, about $1\frac{1}{2}$ in. throughout. After leaving the pylorus, the first 9 in. is named the duodenum ; this bends round towards the back of the abdomen and then approaches the central position, where the remaining length of the small intestine becomes convoluted by doubling again and again upon itself. The whole of the small intestine is **supported** by a **fold** of the **peritoneum,** known as the **Mesentery.** The **Peritoneum** is the membrane that lines

the abdominal cavity and is reflected over the several organs contained therein. Besides the duodenum, two other names are given to succeeding portions of the small intestine—the jejunum and the ileum.

The structure of the walls of the small intestine consists of coats similar to those noted in the stomach, an outer or serous coat, a middle muscular of two layers, circularly and longitudinally arranged, and within the muscular the submucous and mucous coat. The **special feature** of the mucous coat is that in the first portion of the intestine the **coat** is

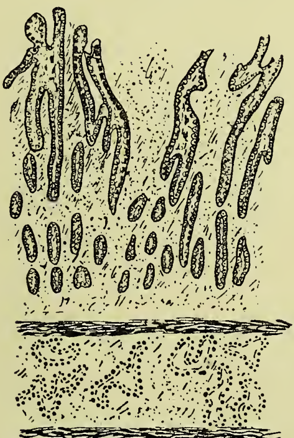


Fig. 53.—Sketch of coats of stomach from micro-section, gastric glands in situ.

freely folded for about two-thirds the distance round the inside of the tube, forming a **series** of **barriers** to the too rapid flow of the **semi-fluid chyme** as it leaves the stomach, and it also **provides** an **increase** of **absorbing surface.** Another feature of the mucous membrane is the presence of **minute elevations,** named **Villi,** along the whole length of the small intestine. These **villi** contain **lymphatic vessels** called **Lacteals,** which are engaged in absorbing the digested

fatty foods. The absorbed fat goes to form **chyle**, and is taken along lymphatic vessels by way of the mesentery to the thoracic duct as explained under the lymphatic system. In the mucous membrane of the small intestine numerous **tubular** and **mucous glands** are found. Their secretion may help digestion in this part of the alimentary canal, but the digestive function carried on in the small intestine is mainly due to the pancreatic juice and bile, which secretions are passed into the duodenum.[1]

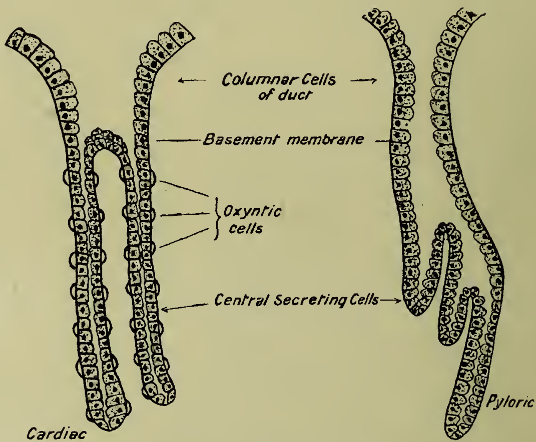


FIG. 54.—Cardiac and pyloric glands (diagrammatic).

The pyloric sphincter muscle relaxes slightly to allow the **partially digested** and **acid food** to pass from the stomach into the duodenum, where the food meets with the **two secretions**, namely, the **pancreatic juice** and the **bile**, and is rendered **alkaline**. It is now in a condition to be acted upon by the ferments of the pancreatic juice aided by the bile. The **proteids** are **changed** by the proteid ferment into **alkaline peptones**, that is, rendered **soluble** and **diffusible**. In this

[1] The chapters on the Liver and Pancreas should next be studied in order to understand intestinal digestion.

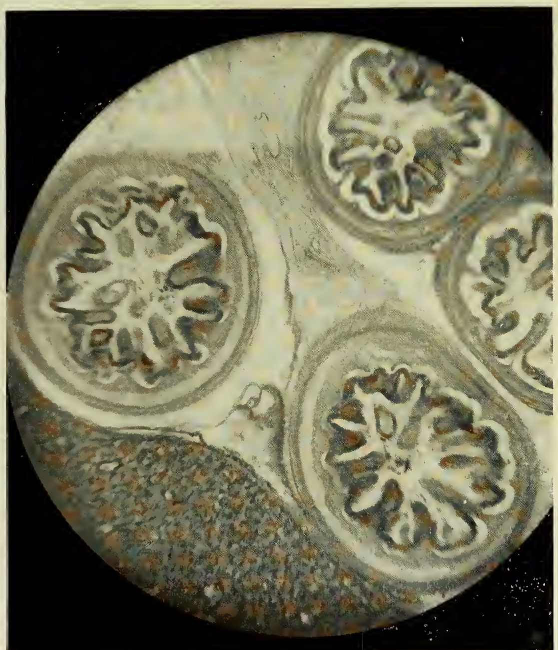


FIG. 55.—PHOTOMICROGRAPH OF FŒTUS TO SHOW VILLI OF SMALL INTESTINE, PORTION OF THE LIVER AND MESENTERY

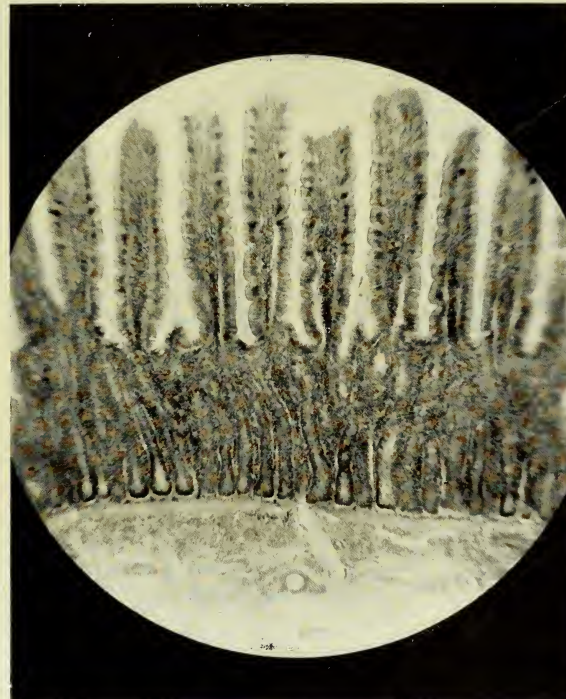


FIG. 56.—SECTION OF SMALL INTESTINE WITH LACTEALS, TUBULAR GLANDS AND SUB-MUCOUS. PHOTOMICROGRAPH × 200

condition the proteids are absorbed into the capillaries of the intestine. Any starchy food present is changed by the **starch-changing ferment** into sugars, and these are absorbed into the blood capillaries.

By the action of a third ferment, the **fatty food** is split up into **extremely small particles,** and by the help of the bile these form a **kind of emulsion.** It is in this condition that the fat of the food passes through the **walls of the villi into the lacteals within.** It then finds its way into the thoracic duct and into the blood system, and becomes a constituent of

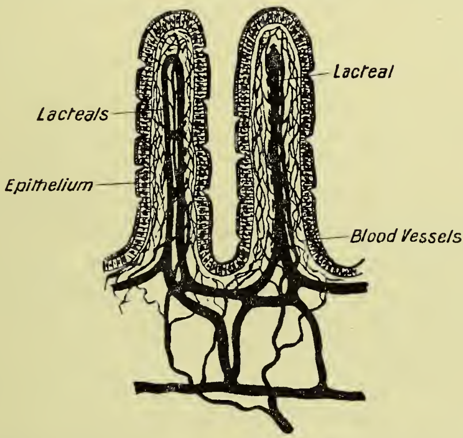


FIG. 57.—Villi to show lacteals, blood vessels and columnar epithelium.

the blood. In the **small intestine much** of the food taken is **digested** and **absorbed.** The digested food passes slowly along this part of the alimentary canal by a series of wave- or worm-like movements spoken of as **peristaltic movements.** The great length, over 20 ft., together with the extensive surface of mucous membrane provided, are **favourable conditions** to allow of the absorption of the soluble food-stuffs.

Large Intestine. The final division of the alimentary canal is about 5 ft. in length and 3 in. in diameter. Instead of being of uniform diameter like the small intestine, it is con-

stricted along most of its length into a series of small pouches, giving it a **sacculated** appearance. It **begins** at the bottom of the abdomen on the **right side,** just within the right hip-bone. The **Ileum** division of the small intestine joins the large at this point, and in doing so it forms a kind of valve, by the infolding of its end, the **Ileo-cæcal** valve. This **valve prevents** the return, after the semi-fluid matters have once passed from the small into the large intestine. **Below this junction** is a part of the large intestine named the **Cæcum,** from which hangs the **vermiform appendix.** **Above the junction** of the large intestine the part is named the **ascending colon ;** this portion ascends on the right side of the abdomen to near the stomach, it next crosses the abdomen just along the lower border of that organ and becomes the **transverse colon,** then dipping to the back it passes along the left side to the bottom of the abdomen as the **descending colon.** After a sharp bend the large intestine terminates in a **straight** and **non-sacculated** portion, the **rectum,** which at its extreme end is guarded by the **anal sphincter muscle.** The large intestine is **supported** by the **mesentery,** and its structure is similar to the small intestine, covered by a **serous coat** on the outside, and lined inside by **mucous membrane.** Between the serous and mucous coats are **longitudinal, muscular fibres.** The longitudinal fibres are gathered into three bands and not spread evenly over the whole surface. These bands are rather shorter than the length of the intestine and cause it to become puckered. **Circularly** disposed muscle fibres are also present.

The **transverse foldings** of the mucous membrane, like those at the beginning of the small intestine, **are absent** from the large, but the **sacculated** arrangement in the large intestine serves a similar purpose, namely, to increase the area of absorption.

Tubular glands are numerous in the large intestine, but **villi** are **absent.** The **function** of the large intestine is chiefly the **absorption of water,** thereby rendering the contents of

the intestine semi-solid before excreting. The **excreta** consist of both **waste** and **innutritious** substances.

GASTRIC DIGESTION. In order to follow the digestive changes produced in proteid foods, it will be necessary to obtain from the chemist a preparation known as Liquor Pepticus. This is an artificial preparation of gastric juice from the stomach of the pig; it contains a ferment **pepsin** and **hydrochloric acid.**

Take some fibrin, obtained by whipping blood, place a small quantity in a test-tube with water, to this add a few drops of artificial gastric juice. Next place the tube in a vessel of warm water, and keep the contents of the tube at a temperature of 37° C. or 98° F. for a short time; occasionally shake the tube. Carefully observe the changes. The fibrin first **swells,** becomes **clear,** and then **gradually dissolves,** that is, becomes digested.

Compare these changes with what happens to proteid food in the stomach. The food meets with an **acid fluid** containing a ferment **pepsin,** it is kept at the **temperature** of the **body,** it is **moved** about by the agency of **muscular contraction,** and after a longer or shorter time the food is **dissolved** or **digested.**

The proteid is now in a **soluble** and **diffusible** condition known as **peptone,** that is, fit to be absorbed from the stomach into the blood capillaries distributed in the walls of the stomach.

Perform the following experiments:—

Experiment 1. Take another **proteid,** say the white of egg, **albumen,** and shake up a little in cold water. Now add a **small drop** of weak copper sulphate, followed by a few drops of potassium hydrate. Reaction, a **violet** colour. This is a test for **proteids.**

Experiment 2. Take a small quantity of the **digested proteid,** add a drop of copper sulphate, followed by several drops of potassium hydrate. Reaction, a **rose-red** colour. This is a test for **peptone.**

Experiment 3. Place some of the egg-white with water in a parchment skin, or in a vessel the mouth of which is tightly covered with parchment. In either case you have a **dialyser.** Next suspend the dialyser in a vessel of cold water. After an hour or two test the **water outside** the **dialyser** for **proteid.**

Experiment 4. Repeat the last experiment, using some of the **digested proteid** instead. Test the water outside the dialyser.

Experiments 3 and 4 demonstrate the **non-diffusible** character of **proteids** and the **diffusibility** of **digested proteids.**

CHAPTER XVIII

THE LIVER

The **Liver** is a large and important **glandular organ,** weighing from 50 to 60 oz. in man and relatively large in most animals. It is a dark red or reddish-brown organ, situated immediately below the diaphragm, into the concavity of which it fits. It is largely on the right side, but reaches across the abdomen towards the left, and is protected by the lower ribs. It rests upon the pyloric end of the stomach, touches the right kidney, and is held to the diaphragm by a thin membrane. The liver should rise and fall with the movements of the diaphragm.

The organ is smooth on the outside and has a large right lobe and a smaller left one, and beneath these are three small divisions, making five lobes in all. These are thick behind and thin in front.

The **lobes** are made up of very **small subdivisions** named **lobules. Each lobule is a collection of liver cells,** and running between these cells is a series of capillary blood vessels and bile-collecting channels. All the lobules are held together by connective tissue, and channels are formed in which blood vessels and bile ducts are found.

The **Liver** receives **blood for nutrition** from the **hepatic artery.** Apart from this, a large quantity of blood passes through the liver, **portal blood,** from the **portal vein.** This vein brings blood from the stomach, intestines, spleen, and pancreas. The hepatic artery and portal vein enter by a fissure

between the lobes into what are called portal channels, the bile ducts also travel along these channels.

The large quantity of blood brought by the portal vein, **blood rich in food material** from the **stomach** and **intes-**

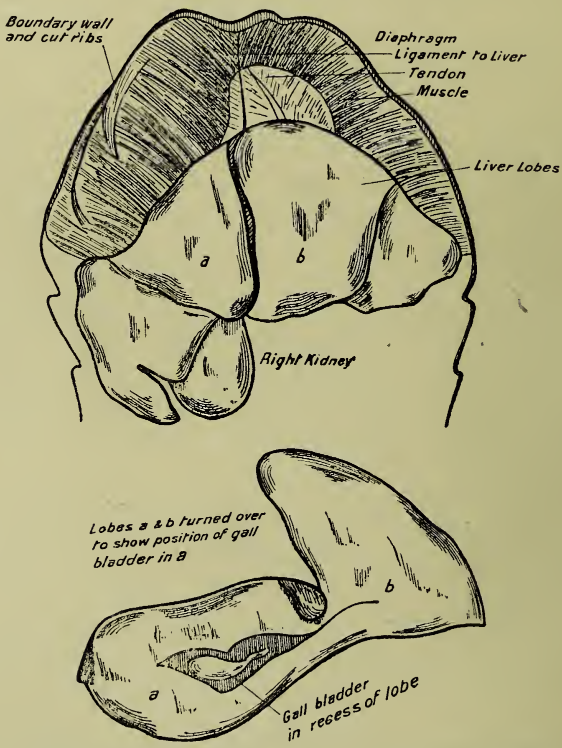


FIG. 58.—Sketch from the abdomen of a rabbit to show position of the liver in relation to the diaphragm and right kidney.

tines, and **blood pigments** and **other products** from the **spleen,** is now submitted to the action of the liver cells. As the blood courses through the capillaries amidst the liver cells, **materials** for the **formation** of **bile** are removed. The bile

formed finds its way into minute channels between the cells, then into distinct ducts, and finally into two ducts, one from the right and the other from the left lobe of the liver, which, on leaving the organ, **unite.**

Thus **one bile duct** is formed which opens into the duodenum near the pylorus. Bile **easily passes** by this duct into the duodenum if food **be present** and the **secretion is**

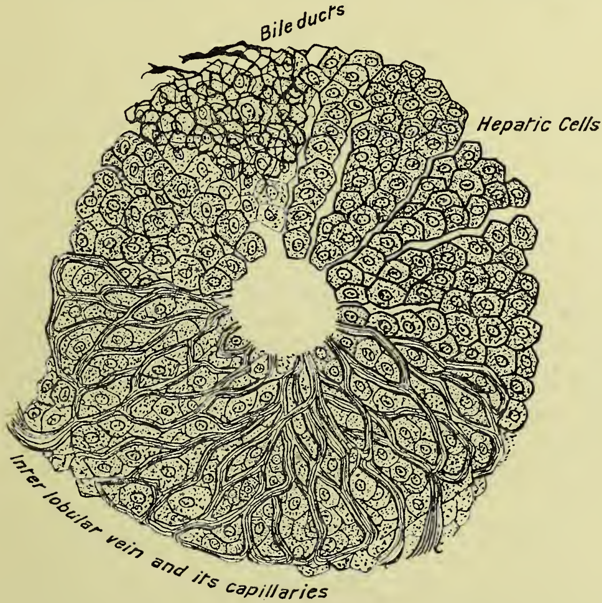


FIG. 59.—A micro-sketch of a lobule of the liver—semi-diagrammatic.

required; under this condition the **mouth of the duct is kept open.** If food **be not present,** the walls of the **duodenum come somewhat together** and **close the opening.** The bile is **constantly secreted** by the liver, but as it cannot pass into the duodenum at certain times, it accumulates in the duct for a short distance back and then **finds** a **passage** by a

branch duct, the **cystic**, which leads to the **gall-bladder**, where it is stored until required.

The **Gall-bladder** is a pear-shaped, muscular, membranous bag, about 4 in. in length, and capable of holding an ounce of bile. **Bile** from its great bitterness is named **gall.** The **gall-bladder** is situated in a depression of the under surface of the right lobe of the liver. When bile is stored in the gall-bladder it becomes thickened by the addition of mucus. As soon as food passes into the duodenum it stimulates the contraction of

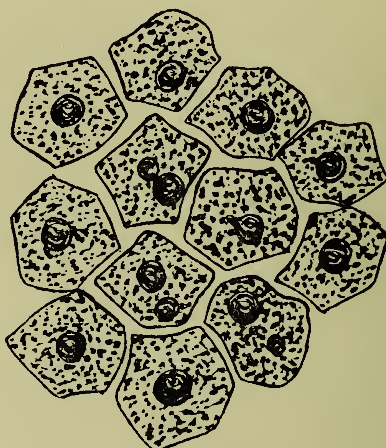


FIG. 60.—Micro-sketch of liver cells (highly magnified).

the gall-bladder, and its contents are discharged to aid in digestion of the food.

Bile is a thin, coloured fluid which becomes thickened by the addition of mucus. Its colour is **greenish-yellow** from **herbivorous**, but of a **golden yellow** from **carnivorous animals**; it is **alkaline** in reaction. Bile contains pigment matters derived from the blood, salts, both inorganic and organic, and other substances. About 40 oz. are secreted in twenty-four hours. Bile **aids** the pancreatic juice in its action on fatty foods.

It helps the absorption of proteids, and stimulates the action of the intestinal canal.

Glycogen. The liver forms from the portal blood other substances besides bile ; glycogen is one of these substances, a kind of animal starch, that is, having similar chemical elements to those contained in starch. It is stored in small granules in the liver cells, and when required this glycogen is acted upon by a ferment and set free in small quantities as sugar, which when oxidized supplies **heat** to the body.

The **Liver** also converts certain substances brought to it into **urea,** an **important nitrogenous waste** excreted in the **urine** by the **kidneys.** **After** the portal blood has been submitted to the action of the liver, it passes by the **hepatic vein** into the **inferior vena cava.**

By these important functions of the liver the composition of the blood is much modified and rendered largely fit for circulation throughout the body.

The **examination** of a **fresh liver** from the rabbit will confirm the above description, whilst the **characteristics** of **bile** may be studied by using the **bile** from the **gall-bladder** of an ox.

CHAPTER XIX

THE PANCREAS

The **Pancreas** is an elongated, tongue-shaped organ lying across the abdomen, with the **broad end** in the bend of the duodenum and the **narrow end** to the left, near the spleen. It is held by a fold of the **mesentery** just under and behind the lower border of the stomach. Its cells are arranged in masses forming **lobules**; each lobule has a duct opening into a **central duct** which runs the length of the pancreas and finally **opens** into the duodenum.

The pancreas is of a **yellowish colour** and **loose** in **structure**; this organ in the lower animals is commonly known as the lower sweetbread.

The **secretion** of this organ is spoken of as **pancreatic juice**—a **strongly alkaline** and **powerfully digestive** fluid. It is **rich** in **solids**, amounting to as much as 10 per cent. Pancreatic juice contains **ferments which act upon three classes of food-stuffs**, viz., trypsin ferment on proteids, amylopsin on starches, and steapsin on fats. It also contains a milk-curdling ferment known as rennin.

The pancreatic juice and the secretion of the liver are poured by ducts into the small intestine, where they meet with the food coming from the stomach. It must be noted that the **medium** in which the **ferments work** in the small intestine is **alkaline**, not an **acid** medium as in the case of the stomach.

The result of the action of pancreatic juice on **proteids** is to convert them into **soluble** and **diffusible peptones**, to be ab-

sorbed into the blood capillaries in the walls of the intestines. The action of pancreatic juice on **fats** is to **convert** them into **emulsions.** The bile aids this action. The fine particles of fat are then pressed into the **lacteals** in the villi, and pass by way of the **thoracic duct** into the blood system. The starch-converting ferment of the pancreatic juice changes the starch into the soluble form of sugar, which becomes absorbed directly into the **blood capillaries** of the **intestine.**[1]

Summary. The several kinds of food-stuffs are considered in separate chapters, and it is only necessary here to summarize the digestive processes. **Mouth digestion** includes mastication, softening of the food by the saliva, and the action of the ferment ptyalin on starch, changing it into grape sugar.

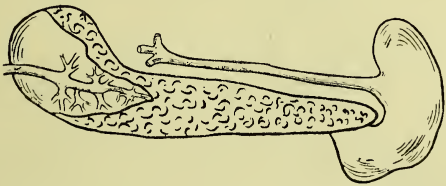


FIG. 61.—Pancreas and its ducts. The spleen and its blood vessels.

Thorough mastication helps the other processes and prepares the food for swallowing. When the pulpy mass reaches the stomach, **gastric digestion** begins by first making the **alkaline** mass **acid** by the gastric juice. The **presence** of the food in the stomach helps the flow of gastric juice and also the contraction of the muscular walls of the stomach. The gastric juice becomes thoroughly mixed with the food and the **ferment pepsin** changes the proteids into soluble substances; there is no **chemical action** on fat or starch.

Some of the **soluble foods** will be absorbed by the blood

[1] Similar **experiments** to those given in connexion with the gastric juice should be carried out with **artificial pancreatic juice.** This may be obtained from the chemist under the name of **Liquor Pancreaticus.**

vessels of the stomach. The **partially changed** food is next passed on to the duodenum, squeezing through the pylorus as the muscular ring relaxes. Next, **digestion** in the **intestines takes place.** The food is acid as it is received from the stomach; it is first rendered alkaline by the pancreatic juice and bile, both alkaline fluids, and then the proteids, fats, and starches that are present are digested.

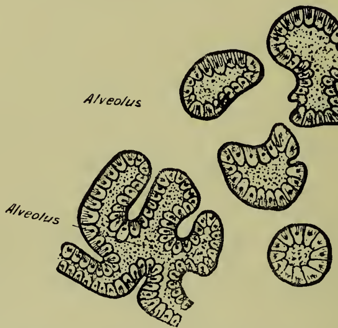


FIG. 62.—Sketch of lobules and secreting cells of pancreas (micro-section.)

The **fatty matters** are taken up by the **lacteals,** and as the semi-fluid mass **passes over** the **mucous membrane** of the small intestine by the wave-like action of the muscular walls, all other soluble substances become absorbed by the blood capillaries. **Finally,** the **insoluble** and **waste substances** pass on to the large intestine, water is gradually absorbed, and the contents become semi-solid.

CHAPTER XX

THE SPLEEN

The **Spleen** is an organ closely associated with the functions of the liver and the composition of the blood. It is situated on the **left side** of the abdomen against the cardiac end of the stomach and protected by the lower ribs ; foldings of the **peritoneum** hold it to the stomach and diaphragm. The colour is dark and of a purplish shade, about 5 in. in length and of a flattened, oval shape. The side against the stomach is depressed and named the hilum ; here the splenic artery enters and splenic vein leaves.

The spleen is **enclosed** in a **thin capsule,** and passing from this internally are many branchings of connective tissue and pale muscle fibres which divide the interior into spaces ; a very fine tissue, of cells with numerous branchings, fills in the spaces. This latter tissue together with blood and large numbers of colourless corpuscles form **spleen pulp.** The organ is of a spongy nature, and when cut across looks like a mass of dark-coloured pulp. The spleen of a rabbit is elongated and of a reddish-brown colour. Obtain a piece of milt, the spleen of the ox, and examine it to confirm the points of structure.

The blood enters the spleen by the splenic artery, which breaks up into smaller branches, but the very small arteries do not end in capillaries. The blood on leaving the small arteries passes into the midst of the spleen pulp, and from this into the beginnings of the veins. The union of the veins forms the splenic vein, which on leaving the spleen joins the portal vein and the blood passes to the liver.

In the spleen, situated on the branching arteries, are small, globular masses of tissue named **lymphoid tissue**, and these become crowded with **lymph** or **colourless corpuscles**. In this kind of tissue white corpuscles divide into two, and so multiply their number, and these pass through the midst of the pulp into the blood. It will appear then that a **function** of the spleen is to provide additional **white corpuscles**. The number of white corpuscles leaving by the splenic vein is greater than the number entering by the artery. There appears to be **another function** carried on by this organ. Among the

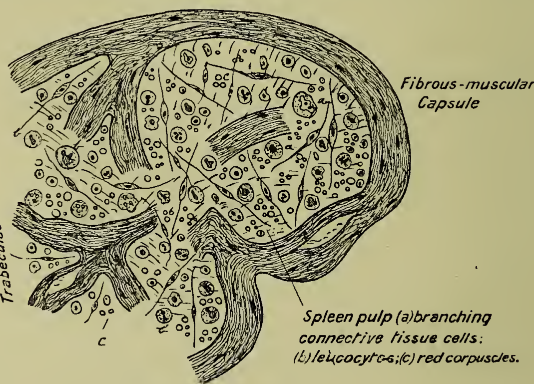


Fig. 63.—Sketch of micro-section of spleen.

large number of **red corpuscles** in the spleen pulp a quantity appear to be broken down or worn out, and the **spleen aids their destruction**. The **red pigment, hæmoglobin**, is not finished with, and this passes with the portal blood to the liver and is of further use in giving **colour** to the **bile**.

The spleen becomes distended by blood at intervals ; it has muscle fibres in its structures, and by these it frequently contracts, aiding the passage of the blood. The spleen is sometimes called a "blood-elaborating gland," and it is a "ductless" gland, having no duct leading from it. It is not, however, a gland in the sense in which we have used this name.

Other structures named "ductless" glands are the Thyroid, the Suprarenal Capsules and the Thymus Glands. Only a brief reference to these is necessary.

Thyroid Gland. Two little cone-shaped lobes joined together by a cross piece situated one at each side of the trachea, just below the thyroid cartilage or Adam's apple: these form the **thyroid gland**, named the upper sweetbread in the sheep. It is a soft and lobulated structure, and about an ounce in weight in a healthy condition of the body; but it often enlarges among persons in certain countries, a condition known as Goitre. Its function is uncertain; it seems to have to do with the nutrition of the body in some way. If it does not act properly in early life it is often the cause of serious conditions of the body and mind.

Situated on each kidney are little ductless glands known as **Suprarenal Capsules.** Their true function is not known; if, however, they become diseased, the body suffers.

Another small gland structure, the **Thymus**, develops by the end of the second year and then gradually disappears. This temporary structure is found in early life just inside the upper end of the sternum.

CHAPTER XXI

THE LYMPHATIC SYSTEM

In addition to the blood vessels there is another set of vessels in the body engaged in **absorbing lymph** and **chyle**, and discharging these fluids into the blood system. The vessels doing this work, together with numerous glands, form what is known as the **Lymphatic** or **Absorbent System.**

The **Lymphatics** consist of capillary vessels, and larger vessels named ducts, and a number of small glands. These structures are found in all the tissues supported by and lying in the connective tissue. In fact, wherever connective tissue is found, it is moist with a fluid lymph, and there are present lymphatics to drain off surplus lymph. The **lymph capillaries** are like blood capillaries, but usually larger and made up of a **single layer** of **epithelial cells.** The capillaries actually begin as so many open spaces or crevices in the tissues; the fluid bathing the tissues drains from these into lymph capillaries, and then into larger vessels like veins—the lymphatic vessels, which have thin walls and contain numerous valves, each valve formed of two small flaps of the lining membrane of the vessel.

The fluid is always pressing forward in the direction of the heart; and as it moves along the lymphatic vessels, it is led into small swellings known as lymphatic glands, in length from $\frac{1}{8}$ to $\frac{1}{2}$ an inch. These glands are very numerous in the neck, armpits, junction of the thigh and the trunk, and on the various organs of the body. They frequently interpose along the course of the vessels, and are formed of collections of very fine connective tissue, known as lymphoid tissue. The **lymph**

is freely passing through these **so-called glands** in its flow towards the heart, **and it gets enriched** by **the addition of colourless corpuscles.** The colourless corpuscles which are

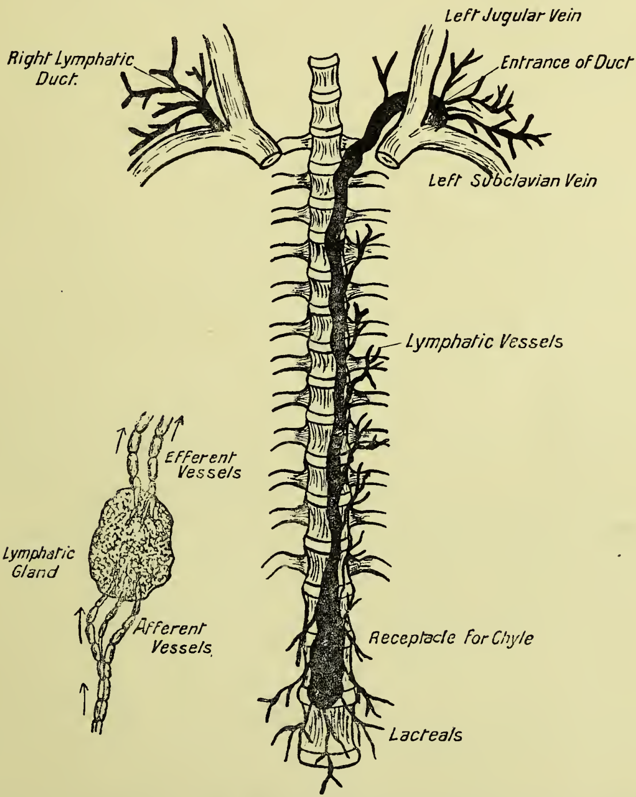


FIG. 64.—Lymphatics. Thoracic duct shown from the second lumbar vertebra to the junction of the left jugular and left subclavian veins. Lymphatic gland and vessels.

found in the lymph have time to multiply, by dividing, whilst passing through the close network of tissue forming the glands. Doubtless other things are eliminated from the lymph while it

is passing through the glands. The lymph, having been pressed forward through these vessels and glands, is passed eventually into the circulating blood by two channels. One is a channel formed by the **convergence** of the **lymphatics** from the right side of the head, neck, right arm, and upper part of the right side of the chest. This is called the **right lymphatic duct,** and opens at the junction of the right jugular and right subclavian veins at the base of the neck. The lymph collected by these vessels gets into the superior vena cava and thence to the right auricle.

The **Thoracic duct** is a distinct duct, and a large number of **lymphatics** and **lacteals** open into it. It begins at the second lumbar vertebra, passes through the diaphragm and alongside the vertebral canal, through the thorax to the base of the neck, and opens at the **junction** of the **left jugular** and **left subclavian veins,** the contents passing by the superior vena cava into the **right side** of the **heart.** The thoracic duct has a diameter of about $\frac{1}{8}$ of an inch. It is similar in structure to a vein, and has many valves. The lower end of the duct is enlarged, and this part is named the **receptacle for chyle.** The **lymphatics** which begin in the **villi** of the small intestine travel over the mesentery and join the lower portion of the thoracic duct. These vessels, which are none other than lymphatics, are engaged in carrying to the thoracic duct during the absorption of fatty matters from the small intestines a milky-looking fluid named chyle, and for this reason these lymphatics are called **lacteals,** from *lac*, *lactis*, milk. When fatty substances are not being carried by the lacteals then, like the lymphatics, they contain only lymph. The thoracic duct also **receives the lymphatics from all parts of the body,** except those joining the right lymphatic duct.

Lymph is a pale yellowish fluid which bathes the tissues; it contains colourless corpuscles and will form a clot if left exposed to the air. It is like blood plasma, in fact, it is plasma which has been exuded through the capillary walls to nourish

the tissues. The tissues have taken all they require, and the **surplus is gathered up,** or absorbed into the lymphatics, and conveyed back by the thoracic duct and by the right lymphatic duct into the blood system to be again circulated. The lymphatics have conveyed into the blood system more than surplus plasma or lymph, for the lymph has been **mixed** with **chyle** in the thoracic duct.

Chyle is a milky-looking fluid formed by the addition to the lymph from the small intestines of **finely divided particles of fat,** in the form of an **emulsion. It is lymph plus fatty particles.** It will be noted here that when digested fat is added to blood it is absorbed by the lacteals and goes by way of the **thoracic duct,** whereas **all other food-stuffs** when digested are absorbed by the **blood capillaries** in the **stomach** and **intestines** and **go direct** into the blood circulation.

The lymphatics are **colourless vessels,** unlike blood vessels, and can only be made visible by being injected with something, such as quicksilver. The lacteal vessels are **visible,** as milky-looking vessels, when charged with **chyle.**

The lymphatics and lacteals are engaged in carrying fluids only one way, i.e., towards the heart. The **passage** of the contents of these vessels will be **aided** by any **external pressure,** such as the contraction of the muscles and the movements of the organs. The **walls are thin,** and there are **numerous valves,** so that any pressure external to the contents must help on the liquids. Some **muscular contraction** of the walls of the lymphatics and also some pressure outside from the lymph in the tissues will help the circulation towards the heart.

CHAPTER XXII

FOOD AND NUTRITION

The animal body as a machine differs from other machines by being self-repairing and self-renewing. Given the raw material in the form of food, the body by a series of mechanical and chemical actions converts the food into a condition to nourish and renew its tissues.

The weight of an average size man is taken as 154 lb., distributed as follows :—

Bones	24 lb.
Muscles . . .	66 ,,
Skin	12 ,,
Fat	27 ,,
Brain and Spinal Cord .	4 ,,
Viscera	13 ,,
Blood	8 ,,
	154 ,,

Water, Mineral Salts, and **Organic Compounds** make up the total weight. **Water** enters so freely into the composition of the tissues that nearly **two-thirds** of the total weight of the body is water, e.g., the **muscles,** which form so large a part of the body, contain about 75 per cent of water, whilst the brain and nerves have upwards of 95 per cent of water, and even the hardest structure such as bone has much water.

Water is **essential** to the **activities** of all the tissues, and it forms the bulk of all the secretions and excretions of the body.

Mineral substances are distributed in larger or smaller quantities in the tissues and liquids of the body. The other substances composing the tissues and organs are included under the term **Organic.**

The water, mineral salts, and organic compounds of the body are named **Proximate Principles.** These consist of **Chemical Compounds grouped** under the divisions **Inorganic** and **Organic.** The former include water and mineral salts, and the latter proteids, carbohydrates, and fats.

The **food** consumed by man, although consisting of **proximate principles** similar to those composing the animal body, **undergoes** a **series** of **changes** by **digestion** before it can enter into the composition of the tissues. It is in the province of the digestive functions to bring about these changes.

The following examples of the proximate principles should be considered :—

Proteids. Complex compounds, consisting of the elements carbon, hydrogen, oxygen, nitrogen, associated with sulphur and phosphorus, are found both in animals and plants. They are the **source** of the **nitrogen needs** of the body. Examples of animal and vegetable proteids are: **Albumen,** found in the white of egg and in milk ; **Globulin,** in the yolk of egg ; **Myosin,** in the lean of meat ; **Casein,** in milk and cheese ; **Gluten,** in the flour of cereals and in the potato ; **Legumin,** a kind of vegetable albumen, found in peas, beans, and lentils.

Gelatin, obtained from connective tissue, tendon, and bone, is a proteid, although not of equal value with the foregoing.

Fibrin is a proteid found in blood and therefore not commonly used as food.

Carbohydrates are compounds of carbon, hydrogen, and oxygen, and for convenience, as the name implies, may be regarded as carbon with the elements of water. **Starch** is a typical example of this combination, consisting of $(C_6H_{10}O_5)_n$ or $C_6(H_2O)_n$, and is commonly found in plants. **Glycogen,** or animal starch $(C_6H_{10}O_5)_n$, is obtained from the liver and

muscles of animals. **Sugar,** another form of carbohydrate, found as grape-sugar ($C_6H_{12}O_6$), cane-sugar ($C_{12}H_{22}O_{11}$), milk-sugar ($C_{12}H_{22}O_{11}$), and malt-sugar ($C_{12}H_{22}O_{11}$).

Cellulose ($(C_6H_{10}O_5)_n$), forming the cell walls of plants, is largely **insoluble** and **indigestible.**

Fats and Oils are composed of carbon, hydrogen, and oxygen, but in this case the hydrogen and oxygen are not in the proportion in which they form water. Cream (which is essentially butter-fat), meat-fat, and vegetable oils are examples.

Mineral Salts. These are found distributed in animal and vegetable foods, and are taken into the body as **salts** of lime, potash, soda, iron, and magnesia—as chlorides, phosphates, carbonates, and sulphates. **Vegetable** or **organic acids** and their **salts** likewise enter into the composition of food, especially fruits and vegetables.

Water is taken into the body as liquids or as a constituent of all solid foods.

CLASSIFICATION OF FOOD. For convenience and according to common practice all foods are divided into:—

(*a*) Inorganic	Water Mineral Salts
(*b*) Organic	Proteids Carbohydrates Fats and Oils

The **Organic** is further subdivided into those food substances containing **nitrogen,** in addition to the elements carbon, hydrogen, and oxygen, and those without nitrogen. **Nitrogenous ;** albumen, myosin, casein, gluten, legumin, and gelatin. **Non-nitrogenous ;** carbohydrates, fats and oils, starches, sugars. Having regard to the value of the foods in the body, the nitrogenous division is **essential** to supply the needs of all those tissues containing nitrogen. The bulk of the tissues of the body, especially the muscular, contain nitrogen com-

bined with carbon, hydrogen, and oxygen, and these **demand** nitrogen for **repair** and **renewal.**

Another function of food is to provide for the **production of heat.** The temperature of our bodies is maintained at 98° to 99° F., which is much higher than the surrounding temperature, and, moreover, our bodies are being continually deprived of heat by the colder surroundings. Much heat, therefore, must be generated to meet these demands.

The **Non-nitrogenous foods,** starch, sugar, fat, and oil, from the absence of nitrogen in their composition, cannot supply materials for repair and formation of nitrogenous tissues. These foods have, however, the elements carbon, hydrogen, and oxygen which **upon oxidation generate heat energy.** The carbohydrates and fats are serviceable in the production of **heat** and in **maintaining** the temperature of the body. It is important to note that proteids contain carbon, hydrogen, and oxygen in addition to nitrogen, and are able to contribute to the heat of the system. Whilst sugar, starch, and fat, in the absence of nitrogen, are **unable directly,** at least, to build up the nitrogenous tissues, we cannot, however, rigidly separate the nitrogenous and non-nitrogenous foods into tissue formers and heat producers. From the foregoing considerations it is better to regard proteids as **tissue formers** and **heat and work producers,** and the carbohydrates and fats as **heat and work producers.** The **carbohydrates** contribute to the formation of fat, and it is probable that the non-nitrogenous foods in some way indirectly help to the formation of the nitrogenous tissue.

Mineral Salts are found in all the tissues and are necessary to their structure. The mineral salts also **aid the absorption** of other food substances by varying the density of the liquids, whilst the presence of **water** is **essential** to the **solution** and **transport** of all other foods in the body.

The following table illustrates the **Proximate Principles** occurring in ordinary foods :—

APPROXIMATE PERCENTAGE COMPOSITION OF FOOD-STUFFS

Name	Water.	Proteids	Fats	Carbo-hydrates	Min. Salts
Milk, cow's	87	4	3·8	4·5	·7
,, human	87	2·2	4	6·5	·3
Eggs	74	14	10·5	—	1·5
Bread, average fresh	40	8	1·5	49	1·5
,, wholemeal	34	9·5	1·5	53	2
Beef, lean	75	20	4	—	1
Pork, fat	60	13	26	—	1
Soles	86	12	·5	—	1·5
Herrings	80	10	8	—	2
Salmon	76	15	7	—	2
Cheese, fat	36	28	30	2	4·0
,, medium	46	28	20	3	3
Butter, fresh	12	2	86	—	3
,, salt	14	1	70	—	15
Oatmeal	15	13	6	63	3
Rice	10	5	·1	84·4	·5
Peas and beans	15	22·5	2	57·5	3
Potatoes	76	2	·1	20	1·9
Arrowroot and sago	15	·8	—	84	
Cabbage, boiled	97	·4	·1	·4	·2 1·1 salts 1·1 1·0 fibre
Apples	82·5	·4	—	12·5	1·9 salts 2·7 fibre

INCOME AND EXPENDITURE OF THE BODY.

The **daily loss** occurring in a man's body is between 7 and 8 lb., comprising about 6 lb. of water and 2 lb. of solids. The channels through which the losses occur are :—

The **Lungs,** excreting approximately 35 oz. (CO_2 gas, water, traces of organic matter, and salts).

The **Skin,** excreting approximately 25 oz. (water, traces of salts, organic matter, and CO_2).

The **Kidneys,** excreting approximately 52 oz. (water, organic matter, much mineral salts, and traces of CO_2).

The **Intestines,** excreting approximately 5 oz. (water and solids).

Total amount 120 oz., or nearly 8 lb.

In order to meet the daily expenditure, **given quantities** of proximate principles of food-stuffs must be supplied to the system. It has been ascertained that to permit a man **to do moderate**

work and keep the body in a state of **physiological equilibrium**, i.e., that the body neither loses nor gains in weight, certain quantities of these principles are necessary.

A **standard diet** of 23 oz. of **dry solids**, which is equivalent to about 3 lb. of **ordinary food-stuffs**, is made up of :—

4½	oz. of Proteids.
14½	oz. of Carbohydrates.
3	oz. of Fat.
1	oz. of Salts.
23	oz.

These 23 oz. represent the amount of **chemically dry** or **water-free foods.** But in taking ordinary food-stuffs we require about twice this quantity, say 46 oz. or daily 3 lb. In addition 60 to 80 oz. of water are required to **meet the expenditure.**

By reference to the table it will be seen that **milk** contains all the proximate principles ; and these are in proportions to **meet the requirements** of the body in **early life ;** whence milk is taken as a **type** or **model** food. Apart from milk, which is strictly adapted to the requirements of infant life, the table also shows that **no one article** of food contains all the **proximate principles** and in the **proportions** suited to serve the nutrition of the animal economy. It is therefore expedient on these grounds to select a **mixed diet.**

The **chemical composition** of food-stuffs alone is an insufficient guide in reference to the selection of food. The fact of its **physiological value**, i.e., **digestibility** and **suitability**, must be considered. For example, cheese shows a high chemical value, whilst generally speaking it is not easy of digestion ; other examples will be recognized in the table.

In the several food-stuffs taken into the body we recognize that they contain similar chemical elements to those found making up the composition of the tissues. The muscular tissue, for example, contains proteid, fat, water, and mineral salts ; the

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bones contain proteid, water, and mineral salts, and so with the other tissues. The **food taken**, then, must be suited to **meet the requirements** of the tissues regarding composition.

The tissues are constantly **setting free energy** in the form of work and heat. The **waste matters** resulting from the several activities of the tissues take the forms of carbon dioxide, organic matter, chiefly urea $CO(NH_2)_2$, water, and mineral salts. The waste matters leave the body in comparatively **simple forms** as gas, water, and solids in solution, whilst the food-stuffs which enter the body are **highly complex compounds.**

Oxidation. In order to reduce the complex compounds forming the food and the tissues of the body to less complex compounds which leave the body as waste matters, the important chemical action of **oxidation** comes into play. The **oxygen** entering the lungs, taken up by the hæmoglobin of the red corpuscles, is carried by the blood stream into intimate relation with the **cells** and **tissues.** The oxygen now forms new compounds with elements and compounds which result from the break-down of the tissues. This is spoken of as oxidation, a most important function. It is a **condition of burning**, just as coal, wood, or oil burn by the supply of oxygen gas ; or, when the bodies of animals and plants **decay**, we have a condition of **oxidation.** In these cases, the oxygen forms with the elements of the wood, coal, oil, or the dead bodies of animals and plants, new compounds and sets free others ; in other words it reduces them from complex compounds to simple ones. The **products of oxidation** are carbon-dioxide (CO_2) gas, ammonia (NH_3) gas, water vapour (H_2O), leaving behind the ash, representing the mineral salts.

In the case of **oxidation** taking place in the living body, similar products result as waste, except that, as a rule, the proteid waste takes the form of **urea** instead of **ammonia.** The urea, however, readily passes to the latter condition and gives off ammonia gas.

Oxidation, then, renders the waste substances of the body

into a fit state to leave the body by the organs of excretion, the lungs, kidneys, and skin, as **gas**, **water**, and **solids** in **solution.**

Temperature. Oxygen, in uniting with other elements in the body to form the waste matters, also generates heat by which the temperature of the body is maintained. **All over the body** oxidation is taking place like so many small fires burning and giving heat; the **total result** of this oxidation is to give a temperature to the body of 98·6° F. or 37° C.

It is most important to consider the fact that the oxidation taking place in the body is the **oxidation of the waste matters** derived from the **activities of the tissues**, and not the direct oxidation of the food supplied. The food substances are **first built into the composition of the tissues**, and waste matters appear as a result of the break-down of the tissues. The different kinds of foods, viz., proteids, carbohydrates, fats, and mineral salts are taken in and dealt with in the mouth, stomach, and small intestine, and digested. The objects of digestion are, as already considered, to render the several substances soluble and diffusible. They are **physically** and **chemically changed**, and in this changed condition **fit to be absorbed**, the proteids, carbohydrates, and salts by the blood capillaries of the stomach and intestine, and the fatty matters by the villi of the small intestine. The fatty foods enter by way of the thoracic duct and general circulation, whilst the other foods absorbed are first submitted to the action of the liver before entering the circulation. The whole of the absorbed food is now carried to the tissues of the body and assimilated.

Assimilation. This word is used to mean the taking up by the tissues of that which they require, and **incorporating the materials of the food** into their structures. In this way the tissues are said to be nourished, and repair and renewal take place. The **food** to be of **service** to the body must be **assimilated.** Digestion has three well-marked stages: the **preparation** of the food to be absorbed; next the **absorption**

and **circulation** of the digested food; and finally the **assimilation** of the digested food.

In considering the nutrition of the tissues it will be noted that the tissues are not **directly nourished by the blood.** As the arterial blood courses along the capillaries, a portion of the **plasma** passes out to **bathe the tissues.** This exuded plasma we have considered as **lymph**; it contains the nutritive substances of the food, and through the **medium of this lymph** nutrition is afforded to the tissues. In a similar manner the **cells** of the **glands** are **bathed** with **lymph** from which they obtain the materials for their secretions and excretions. **Oxygen** also is supplied through the **medium of the lymph,** and here it is that the oxidation of waste from the tissues takes place. From the lymph bathing the tissues the waste finds its way into the capillaries and onward to the general circulation, and finally to the organs of excretion.

The **thinness** and **permeability** of the walls of the capillary vessels is of **prime importance** in allowing of the passage of **liquids** and **gases.** The physical law of **Osmosis,** by which liquids of different densities, when separated by a thin membrane the one from the other, tend to diffuse, **in part explains the exchange** taking place in the tissues, that is, the **passage** or **diffusion** of **blood plasma** and **oxygen** out of the capillaries into the tissues, and the passage of **carbon-dioxide** gas and other **waste matters** into the blood capillaries. It must not be overlooked that lymphatic vessels are also engaged in absorbing the surplus plasma or lymph, with the additions of waste substances, from the tissues, as explained in the chapter under Lymphatic System.

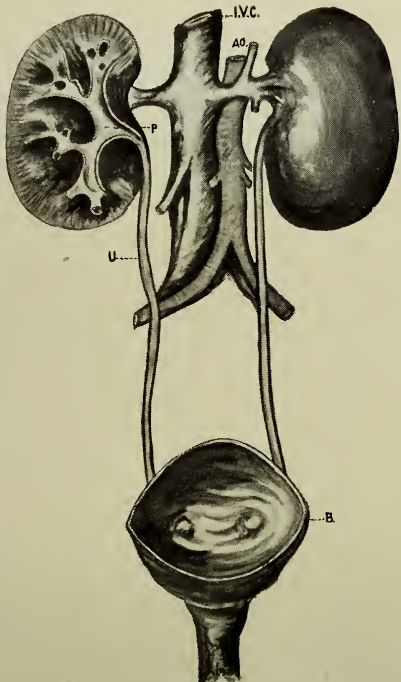

FIG. 65.—THE KIDNEYS. RIGHT IN SECTION SHOWING PELVIS P., URETER U., BLADDER B., AORTA AO., INFERIOR VENA CAVA I.V.C.

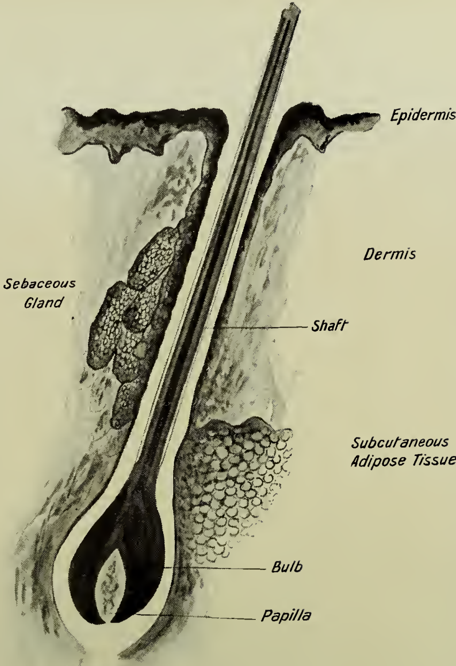

FIG. 69.—SECTION OF SKIN SHOWING HAIR FOLLICLE, HAIR SHAFT, PAPILLA AND SEBACEOUS GLAND

CHAPTER XXIII

ORGANS OF EXCRETION

In carrying on the several functions of the body, that is doing work, much waste results. These waste matters take the form of water and water vapour, carbon-dioxide gas, organic matters, and mineral salts.

These are discharged from the body by the agency of **excretory organs**, the lungs, kidneys, and skin. The products resulting from the activities of the body are taken up and excreted, because they are **unfit** to **serve** any **further purpose** in the **body.**

In the case of the lungs, already considered, the **gas CO_2** forms the **principal excretory product.** Some water in the form of vapour and traces of organic matter are also discharged. This chapter will concern itself with a consideration of the kidneys, and the following will deal with the excretory function of the skin.

The **Kidneys,** two in number, are situated in the abdomen against the lumbar region, one on either side of the vertebral column. The human kidney is about 4 in. in length and $2\frac{1}{2}$ in. in breadth and the colour is dark red or brownish red, and, like that of the sheep, kidney-bean shaped. The depressed side faces the vertebral column and is named the hilus, whilst the greater curvature is turned outwards. The renal artery enters at the hilus, going as a large direct branch from the aorta, and the renal vein leaves at the hilus and enters the inferior vena cava direct. The ureter tube also leaves the kidney at the hilus ; it keeps close against the back of the abdomen near

the vertebral column, and at the bottom of the abdomen it opens into the bladder.

Each kidney is held in position by the artery, the vein, the ureter, and more or less of fatty tissue which invests it.

The arrangement of these parts can be well seen on removal of some of the organs from the abdomen of the rabbit, when it will be observed that the right kidney is higher up than the left, which causes a depression in the right lobe of the liver.

Procure a sheep's kidney and make the following observations :—

Form, size, and colour. A thin skin, the capsule, covers it, and fat adheres to the capsule and also enters the hilus. At the hilus **make out** the **renal artery** and **vein** and the **ureter.** Next make a section dividing it lengthwise. Below the **capsule** there is a dark red portion of some thickness named the **cortex ;** this bounds a lighter or **medullary** portion within. The latter is marked off into a number of **pyramid**-shaped divisions, and the **apex** of **each pyramid** opens into a kind of **cup** and this into a whitish-looking part within the hilus, named the **pelvis** of the kidney. The base of each pyramid is towards the cortex, and parts of the cortex pass a short way between the bases of the pyramids. Squeeze the apex of a pyramid and drops of liquid are emitted, and by pressing the cortex drops of blood may be seen. Further examination of the kidney structures must be made by means of microscopical sections.

The **kidney** is made up of a great number of minute **tubes** or **tubules,** supplied with numerous blood vessels, nerves, and lymphatics, and the whole of these structures are supported by connective tissue making a firm mass. The kidney is spoken of as a compound tubular gland, and is engaged in **separating the constituents** of urine from the blood.

The **tubules** and **blood vessels.** Each tubule begins in the cortex by a **globular end** or **Malpighian capsule,** it then twists and turns, next goes downward into the medullary portion, and then upward into the cortex and thus forms a

loop; then it becomes zigzag and joins a straight tubule which opens at the apex of a pyramid. At the apex are the minute openings of straight tubules. Each tubule is lined with at least three kinds of cells, and these have distinct functions in the separation of the constituents of the urine. Inside the capsule of a tubule is a **bunch of blood capillaries,** named a **glomerulus,** derived from a branch of the renal artery. A **small vessel leaves** the glomerulus, passing out of the capsule, and then forms a **network of capillaries** round about the parts of the tubule known as the convoluted, the twisted, and the zigzag portions. In these parts there are

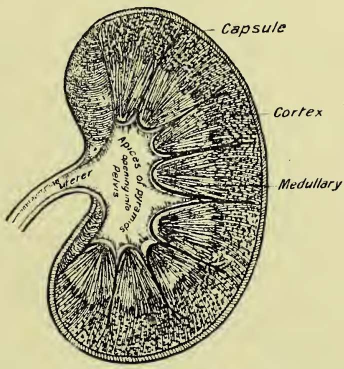

FIG. 66.—Sheep's kidney, sectional view.

secreting cells which remove from the blood water and the more solid constituents of the urine, whereas in the capsule the bunch of capillaries is separated from the tubular part by a single layer of flattened cells, and here most of the water is **filtered** into the tube. The watery portion now helps to carry down the solids, separated by the cells, to the pelvis of the kidney, thence by the ureter to the bladder.

Pelvis and Ureter. The **pelvis** of the kidney is the upper and wider portion of the ureter; as the ureter enters at the hilus the **tube widens** and becomes the pelvis or basin

into which the urine from the straight tubules passes. The urine then continues down the ureter, a fine, white-looking tube 12 to 16 in. in length, to the bladder. The ureters enter the bladder in an **oblique manner,** and when the bladder contracts it closes the mouth of each ureter and **prevents** the urine passing back.

The **Bladder** is a pear or flask-shaped, **muscular, membranous bag,** lined with mucous membrane, and having

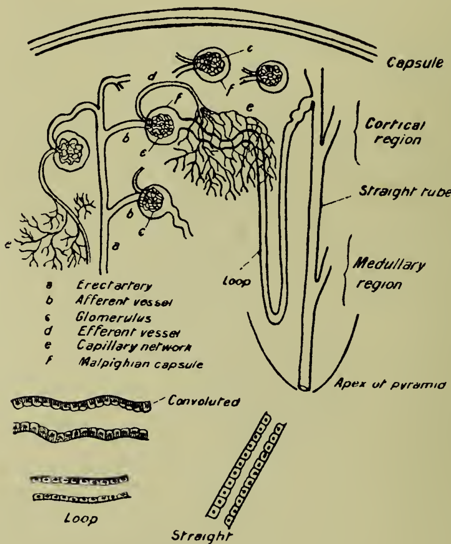

FIG. 67.—Arrangement of the structures of the kidney to show the course of the tubules, cells of tubule seen at different parts.

a capacity of about one pint, when moderately distended. It is lodged in the pelvis of the abdomen and in front of the rectum in the male. The bladder opens to the exterior by a passage, the **urethra,** which is guarded by a **sphincter muscle.** This relaxes periodically to allow of the discharge of the urine. The contraction of the bladder and the relaxing of the sphincter

muscle is under the action of nerves, and these act reflexly. There is a **continual passage** of urine into the bladder, which serves as a kind of reservoir to hold the urine for a given time.

Urine. About 52 oz. of urine are passed daily by a man of average weight and size, containing about **50 oz. of water** and **2 oz. of solids in solution.** The specific gravity of urine in health is 1015 to 1025; the colour varies, and the reaction when fresh is acid. The solids of the urine readily give an indication of the condition of the system, and an examination of the urine by a medical man affords important information.

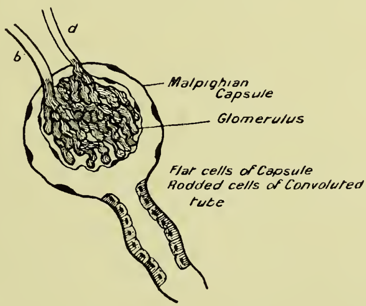

Fig. 68.—Malpighian capsule with glomerulus and beginning of convoluted tubule; *b*, afferent; *d*, efferent vessel.

About **one-half** of the total solids of urine is **Urea,** a compound of CONH. The **nitrogen** in leaving the body is contained chiefly in the **urea.** Urea is formed from the waste of the tissues as the result of work. It is the form in which **nitrogenous substances** leave the body after having served the purpose of building tissues. If **urea** is not discharged it poisons the system. Practically all the urea leaves the body by the kidneys, only a trace by the skin. Urine contains **small quantities of uric acid** and **other nitrogenous bodies. Mineral salts** are excreted in the urine, the chief of which are sodium and potassium chlorides.

The **blood supply** to the kidneys is large, and a special distribution of vessels is found in harmony with the special work of excretion by the tubules. In the case of the kidneys, the **cells** do not **make** or **manufacture** something from the materials taken from the blood, but are simply engaged in **removing** products of waste from the tissues that are **already in the blood.** This is quite different from the work of gastric and salivary gland cells ; these **make new products** out of the substances brought to the glands by the blood. Many things and conditions influence the activity or otherwise of the kidneys. Observe the effect of cold upon the skin, checking perspiration and increasing the activity of the kidneys. When perspiration is free the excretion of urine is less. In winter, then, the kidneys are called upon to do more work, whilst in hot weather the increased activity of the skin relieves the kidneys of some work as far as the excretion of water is concerned.

This mutual relationship between the kidneys and the skin will be better followed after a study of the skin in the following chapter.

CHAPTER XXIV

THE SKIN

The **Skin** covers the whole of the external surface of the body, and serves as an important **excretory organ**, carrying on a like function with the lungs and kidneys in getting rid of waste substances from the system. In order to understand the excretory action of the skin a study of its structure must first be made. The skin covers the voluntary muscles, but between the skin and muscles is to be found a variable quantity of fatty tissue, often in large quantities in stout persons. Fatty tissue gives plumpness to the body, and helps to conserve the heat of the body. In poorly nourished and starved persons the skin shows a leanness and a wrinkling. The fat beneath the skin is named subcutaneous. Above this is the true skin or dermis, and resting on this the epidermis. Included in these two layers are sweat glands, sebaceous glands, hair follicles containing hairs, nails, blood vessels, and nerves.

The **Epidermis** or **outer skin is cellular**, composed of several layers of cells variously modified. The **lowermost** cells are soft and moist, growing and reproducing, and they **get nourished** from the blood supply in the dermis. As the cells get pushed up they become **flattened by pressure**, and at the surface are reduced to a **scaly** condition, of a **horny nature** and are **dead**. These epidermal cells are so minute and thin that they constantly pass off the body without notice. In the case of fever they are noticed in flakes, a condition of "peeling". No blood vessels and no nerves actually pass into the epidermis, at least not beyond the bottom cells. It is said to

be **non-vascular** and **non-sensitive.** In parts of the hand where the skin is thickened by pressure, thin slices can be cut without pain and without drawing blood. The skin sometimes becomes blistered, that is, the epidermis separates from the dermis by the presence of a collection of watery fluid or lymph. This lymph is exuded plasma, and by its means the lowermost layer of cells named the Malpighian layer **gets nourished.** The cells of this layer grow, repeatedly divide, and supply all the cells above. This **Malpighian layer** of cells contains the pigment or colouring matter of the skin, which is abundant in coloured races.

The **Dermis,** in contrast to the epidermis, is **fibrous, not cellular ;** numerous **bundles of white fibres,** among which are **many elastic fibres,** cross and recross to form a **tough** and **elastic** structure. It is this part of the skin in animals which becomes tanned into leather. The lowest portion of the dermis is looser and forms a network of tissue, in which is held the **fatty** or **subcutaneous tissue.** The dermis at its **upper surface** is raised into minute elevations, or **papillæ,** giving an undulating character to the skin. In the palm of the hands and fingers the regular arrangement of these papillæ produce the numerous ridges. At the tips of the fingers the patterns of these ridges are so distinctly marked that they serve for identification of individuals. Place your finger-tips on some printer's ink and make a register of the papillary ridges.

Blood vessels and **nerves** are very numerous in the dermis ; they pass into all the little elevations, and the presence of the **nerve endings** in the **papillæ endows** the skin with the **sense of touch.**

The **hairs** and **nails** are modified **epidermal cells.** They are not endowed with blood vessels or nerves ; both are cut without giving blood or pain. **They grow,** however, like the epidermal cells, from **sensitive beds.** The bed upon which a nail rests is formed of ridges of **vascular** and **sensi-**

tive tissue, and a Malpighian layer of cells supplies the growth of the nail. The nail is both "quick and dead".

Hairs are formed of cells arranged vertically. They are lodged in the pits or **follicles** in the skin. Each hair grows from a **papilla** in the bottom of a **follicle.** The papilla is **vascular** and also **sensitive.** Demonstrate the latter by drawing out a hair from the skin; as the hair root leaves the papilla you feel pain.

Pigment matter present in the cells gives colour to the hair; the change to grey or white is said to be due to air getting between the cells in the hair shaft. In **many hairs** the centre is occupied by loose cells forming a **pith** or **medulla.** Hair follicles are lined with soft cells belonging to the Malpighian layer, and these cells also line small glands at the sides of the follicles, **sebaceous** or **fat-forming glands.** The cells of the sebaceous glands form an oily or fatty matter, which becomes discharged into the follicle; this oily matter anoints the hair, helps to keep the skin supple, and serves as a protection against the action of irritating substances. Hairs are said sometimes to "stand on end" in the case of fear; or the effect of cold at times will cause the skin to crease, "goose-skin," and the hairs to pass from the slanting to the erect position. The explanation is that some muscle fibres below the skin and connected with the outside of the follicles **contract under nervous influence,** and cause the follicles to be lifted up a little; the hairs become erect, and the skin creases.

Sweat Glands are the important excretory structures of the skin. They are widely distributed and are abundant in certain parts, such as the palms of the hands, soles of the feet, and armpits. Press the end of a finger and notice on the ridges tiny drops of sweat, forming rows of shining drops. These points or **pores,** each $\frac{1}{600}$ of an inch in diameter, are the openings of the ducts which pass **cork-screw fashion** through the epidermis into the dermis, where they form **small coils,** the

sweat gland proper. The total length of a sweat gland is about $\frac{1}{4}$ of an inch, it has a lining of cells, and on the outside a network of capillary blood vessels.

The number of sweat glands in the skin has been estimated at over two millions, and there is the addition of sebaceous glands which make up probably six to seven millions, a remarkable drainage system for the body.

PERSPIRATION is a watery fluid containing traces of organic matter, mineral salts, and carbon dioxide gas. On the surface of the skin it is usually mixed with the fatty excretions of the sebaceous glands. Sweat has a characteristic odour.

EXCRETION OF SWEAT. The sweat glands are always active, but the excretion **usually** evaporates from the surface of the skin as soon as it is formed. This is named **insensible perspiration,** but when the excretion **accumulates** on the skin it is named **sensible perspiration** or **sweat.** Sweating **usually depends** upon the **activity of the cells** of the glands and the **supply of blood** to the glands. **Cold** to the skin, acting through the **nerves** to the blood vessels, **causes** the vessels to contract; there is less excretion of sweat. **Warmth externally** will cause a **relaxation** of the blood vessels, and **increased activity** of the cells and **free sweating follows.** Other conditions will influence the activity of the sweat glands, e.g., exercise, fear, pungent things in the mouth, and certain drugs.

TEMPERATURE. The skin whilst performing the **excretory function** of getting rid of **waste matters** from the system has also a **regulating function** to perform in relation to the **maintenance** of a **constant temperature.** The temperature of the body in health is 98·6° F. or 37° C. Test it by placing a clinical thermometer under the tongue or in the armpit. Observe that the temperature is the same whether the day be cold or hot; if you feel hot or cold you still get the evidence that the **actual temperature** of your body is **constant.**

Heat is being **constantly produced** in the body, and as

frequently lost. When you **exercise** the muscles you feel warmer, so by the exercise or **work** of the several organs of the body **heat** is **produced.** In doing work there is the using up of food, there is the wasting of the tissues, and all this means **oxidation,** and the production of heat.

Oxidation, the union of oxygen with other elements and compounds, is taking place all over the body, and **heat** is **generated.** If more heat is produced in one part owing to **greater activity** and **oxidation,** then by means of the circulation it is speedily distributed to other parts. More heat produced in the internal organs will soon find its way to the skin, and some of it passes off by radiation, convection, and evaporation. The food we take has to be warmed to the temperature of the body before it can be digested. The expired air carries off heat, and heat is likewise lost from the body by the perspiration and by the urine.

When we **take food** and **feel warmer** there is really more work being done in **assimilating it,** and **more heat produced.** If we abstain from food there follows **less activity** and **less heat** is **generated,** but there is **less lost.** The skin largely controls the loss of heat, and maintains the constant temperature of the body. We aid the skin to conserve the heat by the use of suitable clothing.

The objects served by **oxidation** are to produce sources of work and heat in the system, and to convert the waste matters of the body into a condition fit for excretion, as water (H_2O), carbon dioxide (CO_2), urea (CON_2H_4), by the lungs, kidneys, and skin.

CHAPTER XXV

THE ORGAN OF VOICE

The **Larynx** or organ of voice is essentially a **cartilaginous box** situated at the top of the trachea and connected with the root of the tongue. It is felt at the front of the throat as a prominence named Adam's apple. To follow the description of the structure of the larynx the student is advised to procure a sheep's throttle and examine the parts in a fresh condition. The **large cartilage** bounding the front of the larynx is the **thyroid.** The broad front, with a median prominence, bends round at the side but is **incomplete** behind. The **back** is occupied by the **second** or **cricoid cartilage.** This has the form of a signet ring, the **broad** portion at the back and the **narrow** portion in front. The large thyroid cartilage **articulates** with the cricoid, at the **lower end** and **back,** by two small horns of cartilage. Two small horns from the **upper portion** of the sides of the thyroid **connect** this cartilage with the **hyoid bone** by **ligaments.** On the **upper edge** of the broad portion of the cricoid are two small, triangular-shaped **arytenoid cartilages.** These **articulate** on the cricoid, and can rock inwards, outwards, and forwards when acted upon by certain muscles.

The cricoid cartilage is connected with the first ring of the trachea by membranous tissue similar to that found between successive rings of the trachea. Between the front of the cricoid and the thyroid is a ligament. Within the front upper portion of the thyroid, a piece of cartilage shaped like an oval leaf, is the **epiglottis.** It has a freedom of movement, and as

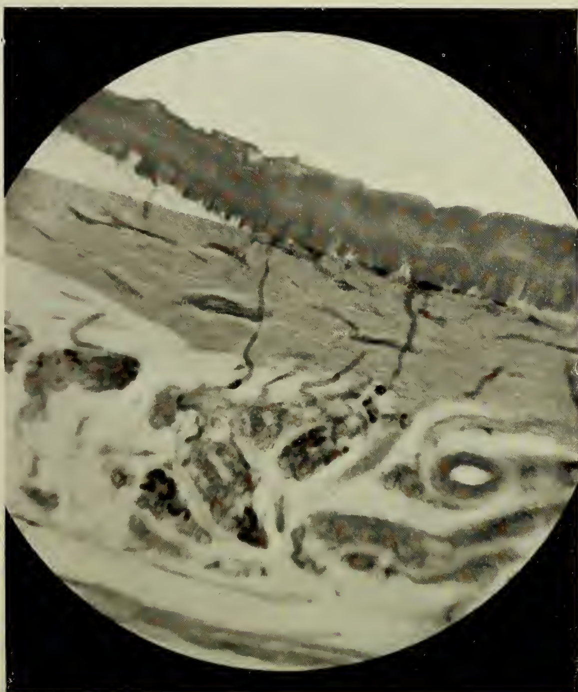

FIG. 70.—VERTICAL SECTION OF SKIN SHOWING EPIDERMIS, DERMIS, SWEAT DUCTS AND GLANDS. PHOTOMICROGRAPH

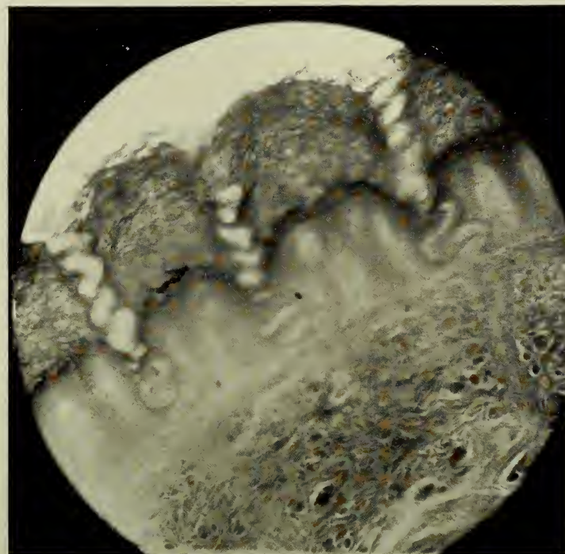

FIG. 71.—SECTION OF SKIN OF FINGER TO SHOW THE SPIRAL PORTIONS OF THE SWEAT DUCTS PASSING THROUGH THE EPIDERMIS PHOTOMICROGRAPH $\times$ 200

the larynx ascends the epiglottis readily **closes** over the **slit-like glottis below.**

The thyroid and cricoid cartilages form the front, sides, and back of the larynx. The arytenoid cartilages have bands of elastic tissue, the **vocal cords,** attached to their anterior end; these bands stretch across to the **inside** of the **thyroid,** that is, **across** the **air passage** leading from the trachea. The whole of the cartilages of the larynx on the inside are lined with **mucous membrane** which is covered with ciliated **epithelial cells.**

From the arytenoid cartilages to the inside of the thyroid are **muscles** running close alongside of the **vocal cords.** Other muscles are found at the **back** and **sides** of the **arytenoid.** On the outside of the cricoid cartilage, on each side and passing to the thyroid, are the crico-thyroid muscles.

The **object served** by this arrangement of **cartilages** and **muscles** is to act on the vocal cords; first to alter their **tension** across the air passage in the larynx, next to bring them **close together.** The passage is V-shaped when air is passing freely, but when voice has to be produced the arms of the V come nearer together. Reference to the several figures will make the structure of the larynx clear.

Voice. In the **stretched** and **parallel** condition, the vocal cords are set vibrating by the passage of air from the lungs, and **sound** or **voice** is produced. If the sounds produced are **regular** we get a **musical note,** and the high or low note depends upon the amount of stretching or tension of the vocal cords. Apart from the particular form and size of the larynx giving the kind of voice, the question of range and accuracy of pitch will depend upon training, that is, in **gaining control** and **power over** the muscles of the larynx.

Speech. After the sounds have been produced due to the vibration of the vocal cords, constituting voice, they have to be **modified** or **modulated** to form **speech.** The parts above the larynx, the pharynx, nose, mouth, tongue, teeth, and lips more

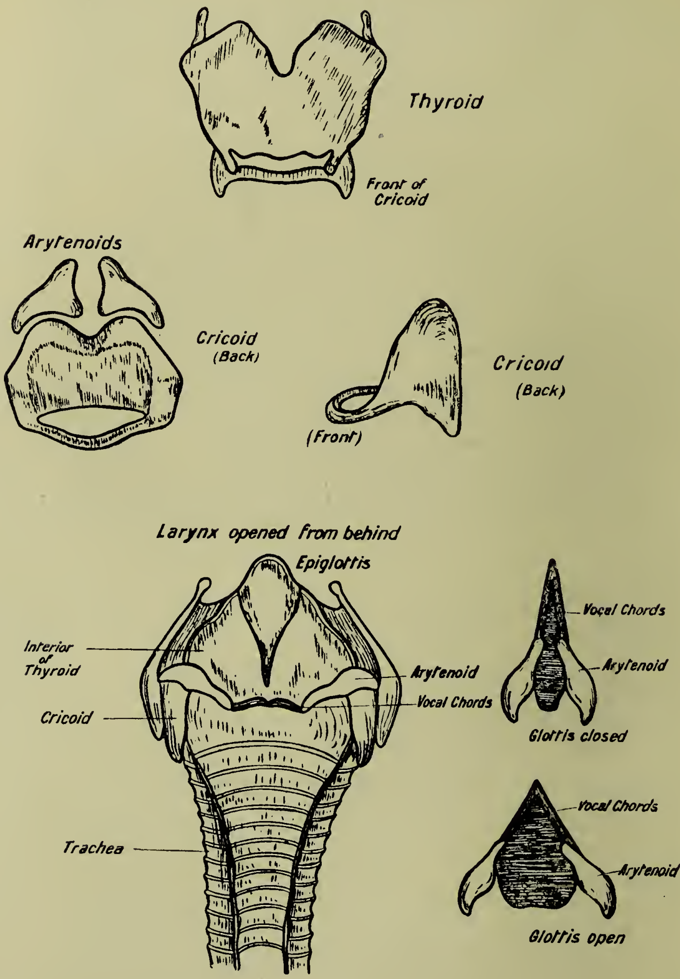

Fig. 73.—Sketch of sheep's larynx opened from behind to show position of the cartilages and vocal cords. Separate figures of the cartilages and two conditions of the glottis are given.

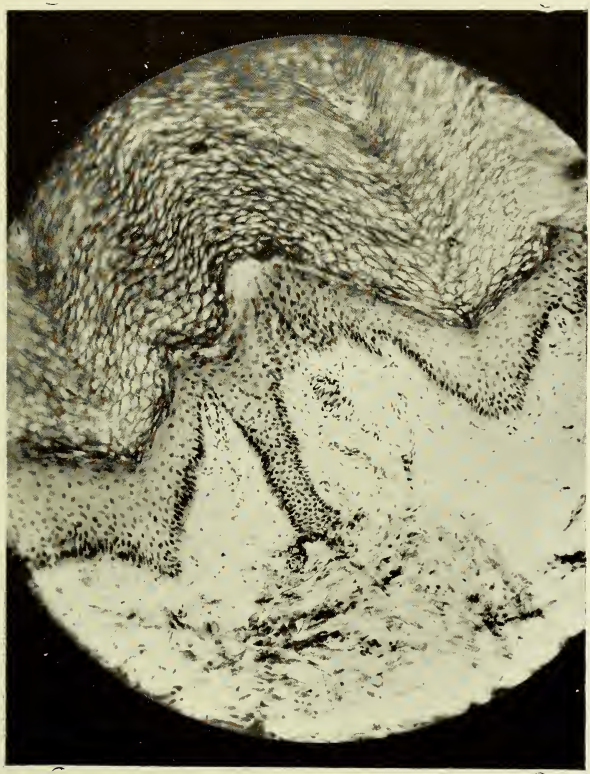

FIG. 72.—PHOTOMICROGRAPH OF SKIN TO SHOW EPIDERMAL CELLS AND MALPIGHIAN CELLS AT THE BASE. A TACTILE CORPUSCLE IS SHOWN IN A PAPILLA AND AN OVAL OR PACINIAN BODY IN THE DERMIS

or less alter the course of the sounds produced. A large number of muscles are called into action to vary the shape of the chambers above the larynx.

When the **pure vowel sounds** are pronounced, as ah, ay, e, o (short), oh, oo, there is a continuous breath, modified by increasing the distance from the throat outwards, and by an alteration of the aperture formed at the open lips. In the case of the sounds to produce the **consonants,** the breath escaping is **checked** by the action of the tongue and lips in the altered form of the mouth cavity. The consonants are classed according to the parts of the mouth or throat called into play for their production.

CHAPTER XXVI

THE NERVOUS SYSTEM

The **Nervous System**, including the brain mass within the cranial cavity, and the spinal cord enclosed by the vertebral canal, with nerves given off from both parts, make up the **central** or **cerebro-spinal system.** A second system, the **Sympathetic**, includes a double chain of **ganglia**, i.e., small collections of nervous tissue, connected by nerve fibres and giving off numerous nerves to the **several organs.** The sympathetic system is composed of a **chain of ganglia** on either side of the vertebral column, the double chain reaching from the neck to the bottom of the abdomen. The **ganglia** have also fine nerves **connecting** them with the nerves from the spinal cord.

Nervous tissue, soft and pulpy, is made up of **nerve cells** and **nerve fibres** supported everywhere by a delicate framework of fine **connective tissue** or neuroglia. Nerve cells are among the smallest cells found in the body, and on the other hand some of them are among the largest cells met with in the body. In some cases plain and unbranched, or having one or two branches, but generally nerve cells are **much branched.** Take a typical nerve cell from the spinal cord. It is large with a large nucleus, and the body of the cell branches until it forms a perfect network of **dendrons.** In addition to the branches, each cell body gives off a single process named an **axon.** This may become clothed with sheathes and remain **unbranched** until it reaches its destination. A **nerve** is a fine **microscopic fibre** about $\frac{1}{2000}$th of an

inch in diameter, but a number of these are bound together to form what is commonly called a nerve ; such may be seen with the naked eye in dissecting an animal. It is necessary to note the structure of a single fibre. Running through the centre is a fine thread of soft, conducting matter, around this is a sheath of whitish substance, and outside this a very thin, membranous sheath. The outer sheath is constricted at intervals and gives a kind of undulating appearance to the fibre ; inside this sheath are several nuclei. The central core is the axon or axis cylinder, the whitish sheath the medulla, and the outer sheath the neurilemma. This is known as a medullated nerve fibre, but there are also nerve fibres without the medullated sheath, and these are known as non-medullated fibres. The latter branch freely, while the others, as a rule, do not branch.

A nerve centre is a collection of nerve cells and nerve fibres. The grey matter of the brain and the spinal cord, as well as the numerous ganglia, being composed of cells and fibres, form nerve centres. The white matter of the nervous system is made up of nerve fibres. These conduct nervous impulses to and from the centres. The centres receive impulses, originate impulses, change and transfer impulses.

Nervous impulses arise from some form of stimulus received on a specialized surface. If the impulses travel inward to a centre they are afferent, and if they give rise to a sensation they are also sensory. When the impulses travel outward from a centre they are efferent, and if they give rise to motion by causing a muscle to contract they are also named motor. Efferent impulses may go to gland cells and awaken secretion. These distinctions, as to the functions of afferent and efferent nerves and nerve centres, are important. Another consideration is that when nerve fibres are distributed to the muscles, to the skin, or to the organs of the senses, for example, the eye or the ear, they have special modified terminations. These terminations are adapted to

receive the particular form of **stimulus.** The nerves we speak of as sensory and motor are alike in their physical and chemical aspects, but **act differently** according to the parts

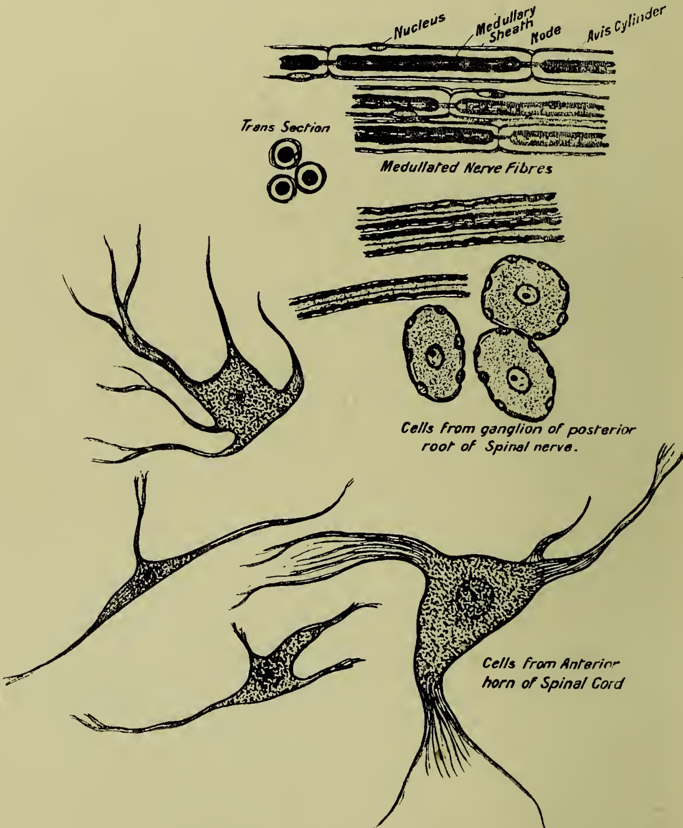

Fig. 74.—Nerve cells and nerve fibres sketched from micro-preparations.

with which they are connected, on the one hand a **centre** that gives rise to a **sensation,** and on the other hand a **structure** that gives rise to **movement.**

Many things are continually taking place in our bodies due to what are termed **Reflex actions.** For example, suppose a stimulus gives rise to an impulse which travels inward by an afferent nerve to a nerve centre, and the nerve centre changes the course of the impulse, causing it to pass by an efferent nerve to accomplish some end, all of which happens without our **conscious** action, we say it is **reflex.** Breathing is due to a series of reflex actions. We are conscious of the movements during our waking hours, but during sleep respiration is still carried on.

These brief explanations of structure and functions of nerve cells and nerve fibres will prepare the way for a short study of the brain and spinal cord.

CHAPTER XXVII

THE NERVOUS SYSTEM (*Continued*)

THE BRAIN. All nervous structures contained in the cranial cavity are usually included in the term **Brain.** For convenience of description we speak of the largest division as the **Cerebrum**; the part behind and under the hinder part of the large brain as the **Cerebellum**, or little brain; the part below this as the **Medulla Oblongata**; and a division in front of the medulla as the bridge or **Pons Varolii.** The whole mass in the human subject weighs about 49 oz. in the male, and in proportion to the less weight of body in the female about 44 to 45 oz. Many cases are recorded of brains which have been weighed after death, in which this average has been exceeded by several ounces.

It is through the brain that the **mind** carries on all the mental functions, but it is not always the case that the largest brain **mass** bespeaks the greatest mind. It is more a question of **quality** than of **quantity,** a smaller brain **well nourished** and **developed** will accomplish more than a larger brain mass imperfectly developed.

The Cerebrum. This division of the brain occupies by far the **greatest space** in the cranial cavity. It has developed to so great an extent in man that it has grown backwards and forwards as to cover in all the lower parts. This is not so in any other animal. Looking down upon the human brain we see no other division but the cerebrum. Not only is this the case, but the **convolutions** or foldings of the surface have become **very involved** and **greatly developed** in the

human brain. This arrangement of convolutions gives a much enlarged area of **grey substance** concerned in **mental functions.**

A specimen of the human brain may not be available for study, but to become acquainted with the arrangement and appearance of the parts included in the brain case, much

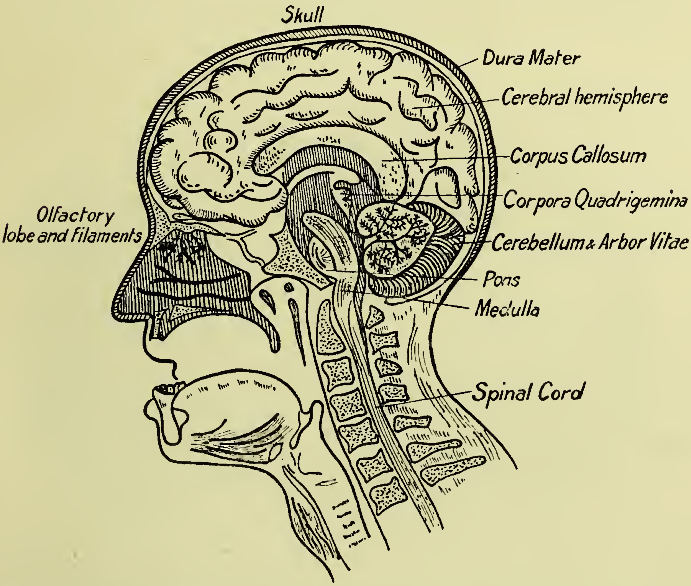

FIG. 75.—Vertical median section of skull and vertebral column to show the parts of the brain and spinal cord in situ.

help may be had by making observations on the brain of a sheep. Procure a sheep's head, and have it sawn through the bony roof of the skull and then split down the middle line. Each half is now entire and observations of all parts can be made.

First, observe the **protections** for the soft, nervous substance, the **bony structure** is thick but not heavy, lined by a

tough, fibrous membrane, the **dura mater.** This membrane protects against the sharp and rough bone. Lift out one-half of the brain and note a number of **white nerves,** some fine and others coarse, passing from the **lower surface** of the brain through the dura mater, and at the hinder part of the skull through the bone by way of very small holes. These are bundles of nerves going to parts of the head. From the **under surface** at the **anterior end** of the cerebral hemisphere, a

FIG. 76.—Human brain. Side view of cerebrum and cerebellum drawn to show a portion of the upper surface.

thick, soft, greyish lobe passes to rest against the bone, separating the nasal chambers from the brain case. This is one of the **olfactory lobes,** which gives off the nerves of smell to the **mucous membrane** of the **nose.** A little way behind this lobe will be seen the optic nerve rather large, proceeding through a hole to the orbit of the eye. By placing the halves together notice a crossing of the optic nerves. Next, notice that **most of the nerves** given off from the under surface

come from the part named the **medulla oblongata.** Count the number, and note there are twelve pairs of **cranial nerves.**

The **Cerebrum** is divided by a great longitudinal division, or **fissure,** into the **two cerebral hemispheres,** but in the section it will be seen they are not quite separated, being held together by a mass of white matter, the **corpus callosum,** near the base of each hemisphere. The hemispheres are **sculptured** on the exterior by winding **convolutions.** Covering all and

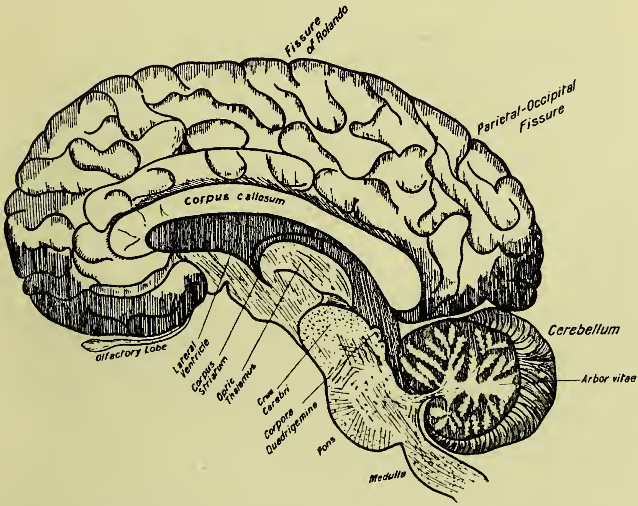

FIG. 77.—Human brain. Vertical median section showing right cerebral hemisphere, section of cerebellum, corpus callosum, optic thalamus, corpus striatum, corpora quadrigemina, pons varolii and medulla oblongata.

dipping into the furrows between the convolutions is a delicate membrane, the **pia mater,** which is full of blood vessels, and is the **medium** through which the brain tissues obtain nourishment.

Cerebellum. Below the hinder lobes of the cerebral hemispheres is seen the little brain or **Cerebellum.** Notice the much smaller size of the cerebellum. Its surface is folded like

a **series of plates** or thick leaves, giving a **laminated** and not a **convoluted** appearance. There is a deep groove partly separating the two lobes of the cerebellum, and the pia mater covers the whole. The vertical **section** through the cerebel-

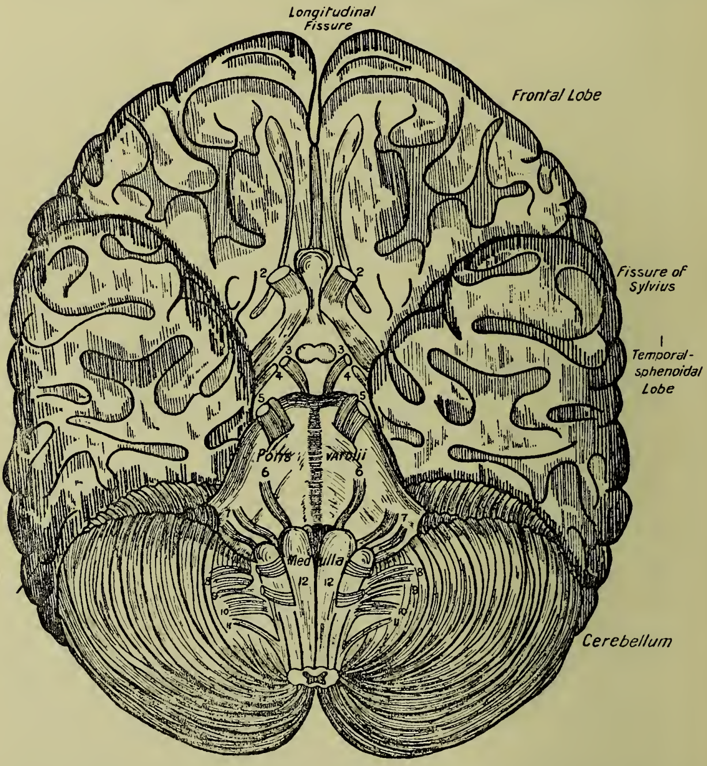

Fig. 78.—Human brain. Basal view showing medulla, pons varolii, optic tract and twelve pairs of cranial nerves numbered 1 to 12.

lum displays what is known as the **tree of life** or Arbor-vitæ. It has a central trunk, branches, and twigs of white matter, with the **infolding** of **grey matter** like leaves, giving a fancied resemblance to the parts of a tree. The cerebellum

is connected in front with the cerebrum, and behind with the spinal cord, whilst midway it helps to form a bridge of whitish matter, the Pons Varolii.

The **Medulla Oblongata,** medulla for short, is about one inch of white-looking substance directly **under** the cerebellum and **behind** the pons, and is separated from the latter by a groove. It is roughly the size and shape of the end joint of a man's thumb, broad in front and tapering slightly behind, to be

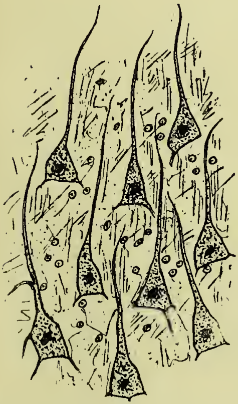

FIG. 79.—Cells from the cortex of cerebrum. Sketched from micro-preparation.

FIG. 80.—Granular cells and cells of purkinje from cerebellum. Sketched from micro-preparation.

continued as the spinal cord in the vertebral canal. Observe the **nerves** given off from the **under surface,** and where cut it has a **pinkish-grey matter within,** and **white matter** on the **outside.** The arrangement of the **white** and **grey** matter is like that in the spinal cord. The **medulla** is a most important part of the nervous system, **containing centres** for **breathing,** for the **heart's action,** for **swallowing,** for the **control** of the **blood vessels,** and other functions.

Injury to the medulla causes immediate death. Note the medulla is situated just within the large opening of the skull at the top of the vertebral column, and the tough, fibrous, dura mater protects it from direct injury.

The **Pons Varolii** is made up of bundles of nerve fibres from the cerebellum, the spinal cord, and the medulla. It forms a bridge of white matter anterior to the medulla and at the base of the cerebrum. It serves to connect part of the nervous system below with the parts above.

Where sections have been made in the cerebrum and cerebellum, **two kinds** of matter have been noted making up the soft nervous tissue. These are spoken of as grey and white, and have been briefly described in a former chapter. The grey matter comprises a mass of remarkable **branching cells** or **neurones, connected** in very complex fashion one with another, and by means of nerve fibres with more or less distinct parts of the nervous system. The white matter consists chiefly of nerve fibres. The outer portion of the cerebral cortex contains remarkable cell structures. These cell structures **receive impulses** from and send **out impulses** to distant parts of the body. Centres for **sensation** and for **movement** exist in the cortex of the cerebrum. Some of these will be referred to after the spinal cord has been described.

CHAPTER XXVIII

SPINAL CORD

THE SPINAL CORD. The spinal cord or spinal marrow is an **elongated mass** of soft, white-looking substance lodged in the vertebral canal. It is about $\frac{1}{4}$ of an inch in diameter, reaching from the base of the skull, where it **joins the medulla,** to the **second lumbar vertebra.** It tapers at the lower end, and its covering of dura mater continues as a thread which is attached lower down to the vertebral canal and serves to steady the cord. The spinal cord is well protected by the vertebræ; it has also a sheath of **dura mater,** a tough, fibrous membrane continued from the lining of the brain case. Inside the dura mater and closely adherent to the cord is the **delicate, vascular pia mater** membrane. Between the dura mater and the vertebræ there is a lodgment of loose fat which serves as a padding.

The **spinal cord** gives off **thirty-one pairs** of **spinal nerves.** These proceed **laterally,** and leave the vertebral canal by the intervertebral openings to become **distributed** to the **skin** and **muscles** of the body. At the neck region and at the lumbar region the cord is slightly enlarged—the **cervical** and **lumbar enlargements.** From the cervical enlargement a number of nerves pass off to supply the arms, and at the lumbar enlargement a large number of nerves come off close together, some of which supply the lower limbs.

The student is urged to procure the spinal cord of a sheep and make direct observations for himself, as all descriptions must appear laboured until the actual object is seen and handled. Figs. 81, 82 will serve as additional aids to the student in making an examination of the specimen.

Right and **left** of the spinal cord a number of whitish threads come off in **two sets**, the **roots** of spinal nerves. The set towards the back, the **posterior roots**, **converge** and join with an anterior set. **Together** these roots form a bundle of nerves, and the **bundle** passes out of the vertebral canal as a **spinal nerve.** Immediately before the union of anterior and posterior roots a small swelling or **ganglion** is seen on the

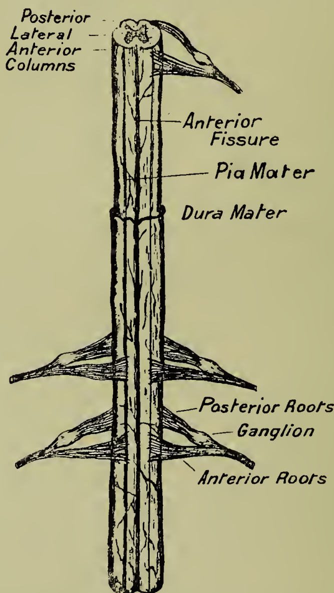

FIG. 81.—Spinal cord of sheep showing spinal nerves.

posterior roots. In this manner the whole of the thirty-one pairs of spinal nerves are formed. A **spinal nerve**, then, is not a **nerve** in the sense of being a **single fibre**, but is a **bundle of fibres** composed of anterior and posterior roots or nerve fibres.

In the dissection of a rabbit the distribution of the spinal nerves can be followed. As the skin is laid out a number of

fine white threads, nerves, are observed. Also in the loose connective tissue covering the muscles, similar threads may be seen. In a **large nerve** passing to the shoulder, or in one found between the muscles of the **back of the thigh**, the **fraying** out of the bundle into fibres is well shown.

Obtain a fresh piece of the spinal cord of a sheep and note the following. The pia mater is marked along one side by a shallow groove with a blood vessel in it. This is the **anterior fissure** which partly divides the cord, and on the opposite side is a **fine line** which indicates the **posterior fissure.** In this way the cord is partially divided into right and left sides, but **connected,** however, by a **central mass** of matter through which runs a very **narrow canal.** When the cord is cut clean across it presents a **pinkish-grey** coloured substance in the central part, around which is some **white** substance. In **each half** of the cord in section it is possible to notice that the **grey** substance has the form of a **crescent** with a **broad anterior horn** and a **narrow posterior horn.** In a thin section of the cord prepared and examined by the microscope these structures can be better followed.

If the observations have been carefully made, the student will be able to connect the several parts of the spinal cord and follow the explanation of their function. The spinal cord has a number of posterior roots connected with the **posterior horn** of grey matter and a number of anterior roots connected with the **anterior horn** of grey matter. The posterior roots have, however, first a connexion with the **ganglion** of the **posterior** root and then pass to the grey matter of the cord, whilst the anterior roots proceed from the **large branching cells** of the **anterior horn outward.** The two sets of roots unite and leave the vertebral canal as a spinal nerve—a **mixed bundle** of posterior and anterior fibres. The **fibres** from the **posterior roots** are distributed to the skin, and endow the skin with the sense of touch, and the **anterior** are distributed to the **voluntary muscles,** and are concerned in **movement.**

By **way** of the **spinal cord** the posterior and anterior nerve fibres **gain communication** with the **brain.** If a stimulus, say the prick of a pin, be applied to the leg, it is felt at once. Now follow what has really taken place. The pin-prick **stimulates** a **nerve ending** of the skin, an **impulse**, i.e., some change passing along a **nerve**, proceeds by an **afferent** nerve belonging to the **posterior roots** to the cord. The impulse is conducted along the cord to the **medulla** and finally reaches the cells of the **cortex** of the **cerebrum.** The **impulse** on arrival gives rise to a **sensation**, or, as in the case under consideration, **we become conscious** of **pain** from a **pin-prick.**

Fig. 82.—Transverse section of spinal cord. Sketched from micro-preparation.

If the prick is severe it may be followed immediately by a movement of the leg. In this case, the reception of the afferent impulse by the cerebrum has caused **certain changes** to follow in the cells and **other impulses have resulted.** This time they are **outward** or **efferent impulses**, and these travel from the cerebrum downward by way of the medulla and spinal cord to the **anterior horn** of grey matter at the level where they pass out. The impulses now leave the cord by the **anterior roots** and proceed by the spinal nerves to the **muscles** of the leg, which **contract** and **movement follows.**

As a deduction from this, all of which has been demonstrated by experiment and observation, the nerves are named as

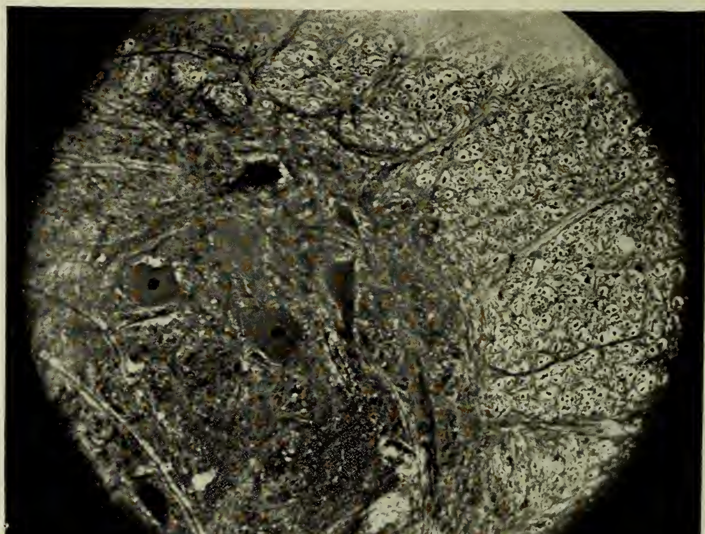

FIG. 83.—TRANSVERSE SECTION OF ANTERIOR HORN OF GREY MATTER OF SPINAL CORD SHOWING BRANCHING NERVE CELLS AND PASSAGE OF NERVE FIBRES. PHOTOMICROGRAPH × 250

follows: those connected with the skin convey impulses **inward** by the **posterior roots** of a spinal nerve, they are therefore **afferent**, and when the impulses awaken **sensation** they are spoken of as **sensory**. On the other hand, impulses travelling outward by the anterior roots are **efferent**, and if movement follows by contraction of the muscles they are also **motor**. The terms **afferent** and **efferent** can always be applied for **inward** and **outward** nervous impulses; but the terms **sensory** and **motor** must depend upon the impulses giving rise to sensation or motion respectively. For example, by the sight of food sometimes there is an increased flow of saliva into the mouth. In this case, the **afferent** impulses, by way of the optic nerve of the eye, have been changed by the brain cells into **efferent** impulses which go to the salivary glands and perhaps to the blood vessels of the glands, causing an **increase** of **secretion**. The impulses outward are **efferent** and **secretory**, but not motor.

The **spinal cord conducts** nervous impulses to and from the brain to all parts of the body, except the region of the head. From the head nervous impulses travel direct to the brain by the cranial nerves, and from the brain direct to the muscles of the face. The **spinal cord**, besides conducting nervous impulses **to and from** the brain, acts as a **nerve centre** or a **series** of **nerve centres**. All the impulses passing into the spinal cord need not, and do not, pass to the brain to be **changed** into **efferent** impulses. This can be shown in the case of a **headless** frog (the frog is without a brain and dead); if the toes are pinched, the legs are **deliberately** drawn up. If the thigh be touched with a drop of acid, the foot of the other leg goes up to rub off the acid. These acts are performed as **purposeful** and as **natural** as if the animal possessed the head and brain. The **spinal cord** has been **educated** to undertake a large number of acts connected with the well-being of the body, without the brain as a rule taking part in their operation. This is a great advantage to us. It allows the mind

to deal with the **higher functions** of thinking, whilst the **nerve centres of the spinal cord** discharge subordinate and instinctive functions. A familiar illustration of this function of the spinal cord is the act of reading a book and taking in the meaning of the subject-matter, while at the same time walking along a road ; the mind is absorbed in the reading, but all the movements of walking are discharged by the **reflex actions of the centres in the cord.** The mind gives attention directly to comparatively few of the numerous complex movements of the body. They are mainly performed by a series of **reflexes** discharged by nerve centres in the spinal cord and other parts of the nervous system.

Reflex Action. This is a power possessed by a nerve centre to **convert afferent** into **efferent impulses** without consciousness. The movements of the organs of respiration, circulation, and digestion are reflex, these and other movements being **essential** to the maintenance of life. Other actions of the body become reflex, that is, performed reflexly after more or less of practice. The movements of the hand and arm in the act of writing have become largely reflex. The **conscious effort** at first, in gaining command of the muscles to direct the pen, has gradually assumed the unconscious condition, and the **action** is **therefore reflex.** The conscious effort manifest in learning to play a musical instrument sooner or later becomes more or less unconscious and reflex. The conscious effort involved in performing any new, or an occasional act, will soon become **easy** by **reflex action** if persisted in. The **habits** of the body are the result of conscious efforts which have become by repetition largely reflex.

This **power** and **adaptability** of the nervous centres in regard to reflex action has an **importance** of the **highest value** in relation to **mental** as **well** as **physical education.**

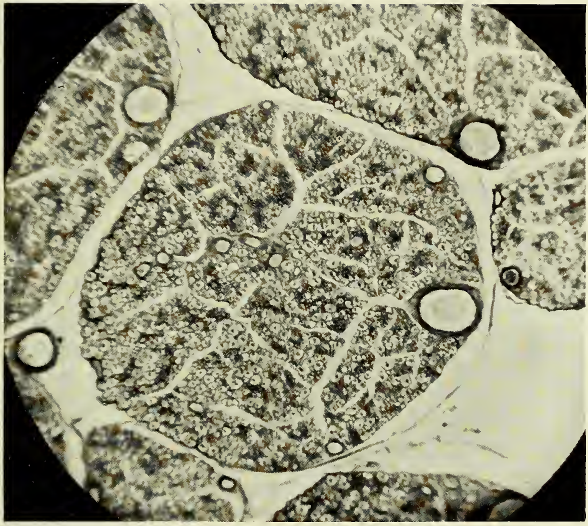

FIG. 84.—TRANSVERSE SECTION OF BUNDLES OF SPINAL NERVE FIBRES LEAVING THE CORD (HUMAN). PHOTOMICROGRAPH × 200

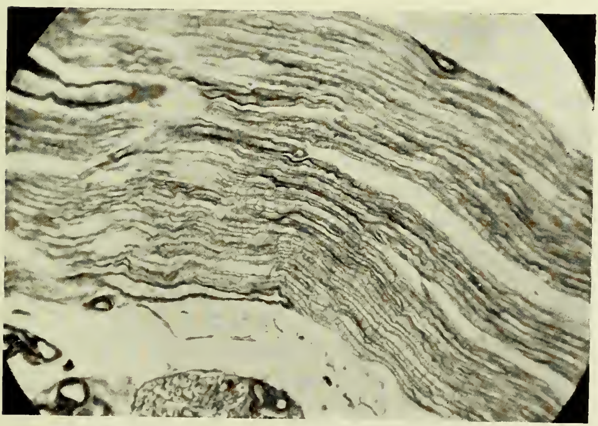

FIG. 85.—SPINAL NERVE FIBRES LEAVING THE CORD (HUMAN). PHOTOMICROGRAPH × 200

CHAPTER XXIX

SENSATION AND THE SENSES

Sensation is a state of consciousness which arises in connexion with the cerebrum. When that which we call **consciousness** or **sensation** arises as a result of afferent impulses travelling inward to the brain from stimuli derived from external objects, we speak of it as **objective sensation.** If the stimulus causing the impulse cannot be directly traced to an external object, but **arises from within,** the sensation is said to be **subjective.** Every moment of our waking life we are experiencing numberless sensations, sensations different in kind and from different parts of the body. Some of these are **well defined** and their source located. We see, we hear, or we touch a thing, and the eye, the ear, and the skin are respectively engaged in seeing, hearing, and touching. On the other hand we have sensations of hunger, thirst, fatigue, comfort, or discomfort, and many others that we do not distinctly locate, being **ill-defined sensations** both in nature and place of origin. They arise from conditions of the body, the circulation, or other more or less obscure causes. From such considerations, sensations more or less defined, such as touch, taste, smell, sight, hearing, are usually said to belong to the **special senses.** These, however, vary in certain features, and in the nature of the stimuli causing the sensations. The sensations known as **pressure** and **muscular** sensations, the sensations of **hot** and **cold,** as well as the sensations of **pain,** are more general in character, and less well defined.

The **conditions necessary** to **sensation** may be recognized

from what has been already explained as (1) a surface to receive the particular **stimulus**, (2) a nerve or nerves to conduct the **impulses** arising from the stimulus, (3) a nerve centre to **receive** and **translate** the **impulse**. The surfaces to receive the stimulus must be **nerve endings** and **adapted** to take up the **particular form** of **stimuli**. These really constitute the **sense organs**. The eye is a sense organ specially adapted to take up stimuli arising from vibrations of light. It will not avail for light stimuli to fall on the sense organ, the ear. If sound waves fall on the taste organ of the tongue, they will not give rise to the sensation of sound. Not only is each sense organ subject to its particular or special form of stimulus; but when the impulse arises at the central organ, the brain, it will be interpreted as coming from that particular sense organ. The organs of special sense are further considered in another chapter. In addition to the five senses a sixth sense may be well recognized.

Muscular Sense. The sensations experienced from resistance to effort may be included in a sixth or muscular sense. Much valuable information is gathered by means of the muscular sense. It informs us regarding the **amount** of **effort** required to perform certain work. It enables us to form **judgments** in relation to the control of the muscles. By carefully comparing the sensations derived from the muscular sense we gain **appreciation** of relative weights. The condition or **tone** of the muscular tissue becomes evident by means of the muscular sense. Like the other senses, the muscular sense becomes of **increasing value** as it is **systematically developed.** The recognition of very slight differences in weight between the various articles handled becomes developed to a valuable degree through the muscular sense. In the case of the muscular sense it will be readily recognized that there are practically **three sensations combined**, namely, **contact, pressure, resistance.** This can be shown by a simple experiment by placing a card on the palm when the back of the hand is rest-

ing on the table. **Contact** of the card is first felt. Now place a weight on the card ; a second sensation of **pressure** is felt. If now the hand be raised bearing the card and weight, a third sensation of **resistance** is felt, in which the muscles of the arm are concerned. This, then, is the sensation arising from the amount of contraction required to **overcome** the **weight** or **resistance.**

TEMPERATURE SENSATIONS. The sensations arising from differences in temperature are largely due to **conditions of the skin.** Hot and cold are relative terms.

The skin at times is nearly as warm as the blood temperature, but often it is many degrees lower. The exposed skin **loses heat** by radiation and evaporation, and also by contact with colder objects ; but the **blood temperature,** as already explained, is constant. The quantity of blood **circulating** in the vessels of the **skin varies,** and there is the **feeling** of warmth or cold accordingly. If the skin has a **free** supply of blood circulating in it, a moderately warm substance will **feel** warmer probably than it **really is.** If the skin has **less** warm blood circulating in it, then bodies touched will **feel** colder than they **really are.** It has been determined by experiments of applying **hot** and **cold points** to parts of the body, say the hand and arm, that there are spots which respond directly to heat, and others, distinct from the first, that respond immediately to cold. Test the palm of your hand, by applying carefully the point of a pencil or bone needle that has been cooled in ice water to different parts of the skin and note the sensations of cold as they are felt. They become very strong in some places. Next, test for hot spots, by warming the bone needle in hot water. Make a map of the areas such experiments indicate. Such experiments suggest the presence of **distinct nerves** for carrying **temperature sensations.** This is likewise the case also in relation to the **sensations of pain and pressure.**

CHAPTER XXX

THE SENSES

Touch. The sense of touch is connected with the whole of the skin covering the body, and it is not absent from the internal surface; the lips and mouth parts evidently possess the sense of touch. The **nerves** supplying the skin are very numerous, and they terminate in several ways. Large numbers end as **very fine fibres** among the cells at the **base** of the **epidermis,** others in **oval** and in **rounded bodies** deeper in the skin and in limited parts of the body, while those that are recognized as more particularly engaged in the sense of touch terminate in many of the **papillæ** of the **dermis.** The **papillæ** are small elevations of the dermis, within which are minute **oval bodies,** about $\frac{1}{300}$ of an inch in diameter, named **touch** or **tactile corpuscles.** In the midst of the tissue forming the tactile corpuscles are the **axis cylinders** of **nerves,** and **covering the papillæ** enclosing these are the cells of the epidermis. When an object is touched, the **nerve ending** is stimulated **through** the **epidermal cells**; if the nerve be stimulated **directly,** the **sensation of pain** is felt, and not that of touch. The stimulus gives rise to an impulse which travels along afferent nerves by the **posterior roots** of a spinal nerve to the spinal cord, onward to nerve centres in the cerebrum, and there gives rise to the **sensation of touch.** As regards this sense of touch there is a marked difference to be noted in the **sensitiveness** of **certain parts** of the skin. The tip of the tongue is nearly twice as sensitive as the end of the forefinger, and the end of the forefinger is twice as sensitive

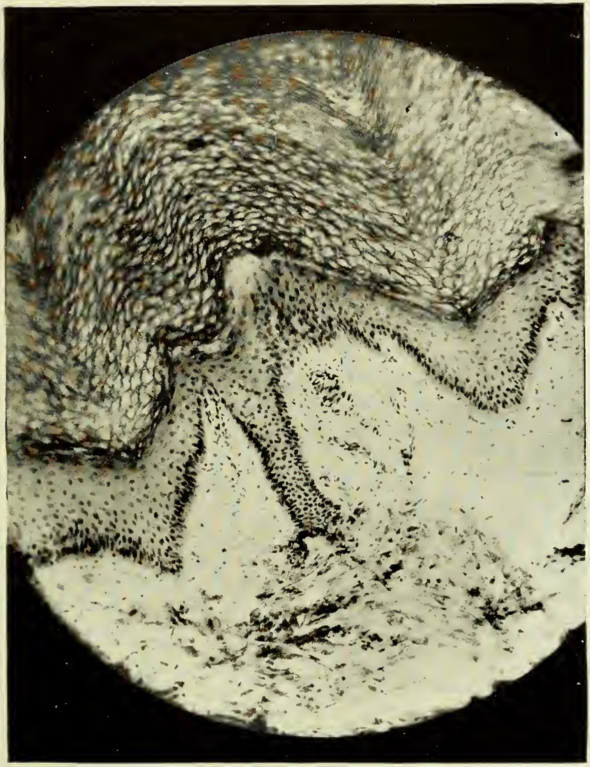

FIG. 86.—PHOTOMICROGRAPH OF SKIN TO SHOW EPIDERMAL CELLS AND MALPIGHIAN CELLS AT THE BASE. A TACTILE CORPUSCLE IS SHOWN IN A PAPILLA AND AN OVAL OR PACINIAN BODY IN THE DERMIS

as the lower lip. Again the palm of the hand has double the sensitiveness of the back of the hand.

Take a pen-nib and press against the points until the tip of the tongue can distinguish two points; measure, then apply the two points to the lower lip. You will find that the spread of the points must be increased in order to distinguish two points. Measure and test the forefinger in the same way. It will be advisable for the operator to use a long, pointed, flexible nib, and the person tested should sit quietly with eyes closed during the test.

The **varying sensitiveness** to touch of different parts of the skin is largely due to the **number** of **touch corpuscles** present in the papillæ of the skin. The sensitiveness to touch will also depend upon the **thickness** of the epidermis. The hands of the manual worker become hard as the epidermis thickens and the delicacy of touch is diminished. On the other hand clever manipulators of musical and other instruments have an advantage in **possessing a thinner epidermis.** Again, the question of **temperature** of the skin is a factor in its sensitiveness to touch, cold making it less so, while numbness does away with the sense of touch altogether for the time being. By **proper care** of the skin its value as a sense organ will be greatly increased. The sense of touch is largely **aided by the eyes**; to see an object as well as to touch it adds greatly to the information gained. Test yourself by keeping the eyes closed and having a strange object placed in your hands. Write down all you gather by the sense of touch, and after compare it with the information gained by the addition of the sense of sight.

CHAPTER XXXI

THE SENSES (*Continued*)

TASTE AND SMELL. These two sense organs are located near one another, the mouth and nose; and often enough what we speak of as **flavours** are strictly **odours**, affecting the nose rather than the mouth. In such cases the sense of smell is stimulated by particles of odour passing from the mouth to the nose by the passages at the back of the nose. A disagreeable substance is taken into the mouth, the nose held, and we don't **taste** it. The holding of the nose is really holding the breath, and you save yourself from inhaling the odour of the substance. There is a blending as it were of the sense of taste and the sense of smell, although the parts concerned are distinct.

TASTE. The mucous membrane of the mouth contains **nerves of touch**, as well as **nerves of taste.** On the upper surface of the tongue the mucous membrane has numerous **projections** known as papillæ. One form of papilla is scattered over the whole surface of the tongue; these have fine thread-like projections, are named **filiform papillæ**, and are largely concerned in the **sense of touch.** The **roughness** of the tongue is due to the **filiform papillæ**, and in the cat and like animals they develop into a strongly horny character, and serve to take up liquids and solid food as well as being useful in combing the fur. **Two other kinds** of papillæ are seen on the tongue, a number with broad tops, the **fungiform**, like minute mushrooms scattered in the midst of the filiform. Then a limited number of large ones, with broad tops entrenched by walls, the **circumvallate papillæ.** These are arranged like > at

the back of the tongue. Projecting from the sides of the **fungiform** and **circumvallate papillæ** are **tapering cells** with fine hair-like processes, arranged in packets, like minute barrels; these form the **taste buds.**

How we taste. The **nerves** of taste have connexion with the hair cells of the taste buds. Around these papillæ with taste buds is the liquid secretion of the mouth; and when things are tasted it is due to some of the **flavouring substance becoming dissolved** in this liquid. The **flavour** then **stimulates** the ends of the projecting cells and impulses

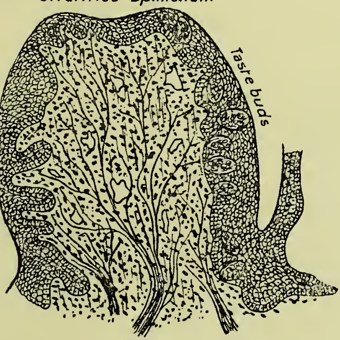

FIG. 87.—Sketch from micro-preparation of a circumvallate papilla showing taste buds and nerve supply (semi-diagrammatic).

FIG. 88.—Taste buds (highly magnified).

proceed along the nerves to the brain, and **we taste. Dry substances** do not affect the nerves; and when the **mouth is dry** we are unable to taste. All parts of the tongue do not **taste alike.** The **front** portion of the tongue is **more sensitive** to **sweet** flavours, whilst the **back** is sensitive to **bitters.** The tongue is **sensitive** to remarkably small quantities of sweet, bitter, acid, and salt flavours. These may be regarded as fundamental flavours affecting the sense of taste. Wine tasters and tea tasters not only **taste** but **smell,** and their

judgments are formed by a **combination** of flavours and odours. The nerves concerned in the sense of taste are the glosso-pharyngeal supplying the taste buds, and the fifth cranial nerve which supplies branches to the front part of the tongue.

SMELL. This sense is associated with the nasal chambers. The nose is divided into the **two chambers** by a septum or partition, bone at the back and cartilage at the front. The completion of the bridge of the nose to the front is also of cartilage. Examine the interior of the nose of a sheep, and observe the **scroll-like**, turbinated bones arranged one above the other in each chamber, and **all parts** covered by a **highly**

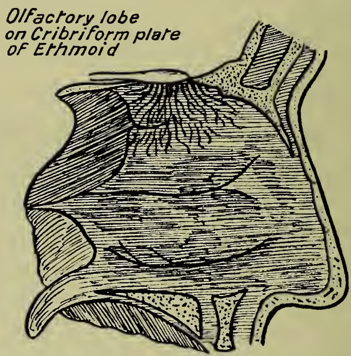

FIG. 89.—Vertical section of nasal chamber to show olfactory lobe and its nerve fibres. See also Figs. 75, 76, 77, 78.

vascular, soft, moist mucous membrane. Over the **lower portions** of this membrane the air passing to the lungs is **warmed**, and also **filtered** of the numerous particles of dust. The **cells** are **ciliated** here like those found in the rest of the respiratory track. Whilst this provision is made in the lower part, the **upper portion** of the chamber has a **special thickening** of the **mucous membrane**, and the **cells are different.** They are long and slender, and **project slightly** from the surface in very fine **projections**, and these are surrounded by the **secretions** of the membrane. In the mucous membrane

are to be found numerous fine nerves, which are derived from the olfactory lobes and pass through the perforated plate of ethmoid bone to reach the olfactory mucous membrane.

This **specialized mucous membrane** is the region of the nose where smell takes place. When particles of odours emanating from substances are inhaled, they come in **contact with this moist membrane, and become dissolved,** and in this condition **stimulate** the **nerves of smell.** If the membrane be **dry** we do **not smell well,** and in the case of **excessive secretion** smell is interfered with. In the latter case the particles may get washed away, or the conditions causing the running at the nose may **dull** the **nerves of smell.**

The **act of sniffing** to appreciate odours better, draws the air in the nasal chambers **out** at the back, whilst the **fresh air** laden with the particles of odour **ascends** into the olfactory region of the nose. The sense of smell in certain animals is very acute; not only are they capable of determining a variety of odours but also are endowed with remarkable power in detecting almost inconceivably small traces of odours. Man trusts more to the sense of vision than to that of smell, the result being in the main due to a special cultivation of the former to the neglect of the latter sense.

CHAPTER XXXII

THE ORGAN OF VISION

The **Eyeballs** are lodged in cavities, the orbits, well protected at the back and sides by the bony walls of the skull, and in front by the eyelids. The orbits are lined by **more or less of fat**, forming a soft bed upon which the eyeballs turn.

It will materially aid to a clear following of any further description if the student will have before him a sheep's head in order to examine the eyes in their sockets, and also two bullock's eyes for dissection. Assuming the specimens have been procured, proceed to make the following observations.

The **Eyelids** have a covering of skin on the outside, and within they are lined by a whitish membrane, the **conjunctiva**; this also covers the white of the eyeball up to the margin of the transparent cornea. The **conjunctiva** is a highly **sensitive** and **vascular** membrane. The sensitiveness of this membrane is recognized when a small object enters the eye, and its vascular character is seen in the case of a blood-shot eye. The upper lid is the larger, and the meeting of the lids perfectly excludes light from entering the pupil of the eye. Between the skin and lining membrane of the lids is some **fibrous** and **muscular** tissue by which the lids are applied closely to the front of the eyeball. The eyelids are opened and closed by muscular action. Just within the eyelashes, at the margin of the lids, may be seen the openings of the **meibomian glands**, which are lodged in the lids. These

glands secrete an oily substance, which prevents the margins of the lids from adhering, and also protects the lids against irritating substances.

Within the eye orbit at the upper and outer corner is situated the **lachrymal** or **tear gland.** It is an oval, lobulated gland with several ducts. The **secretion** of the gland is **constant,** and as it flows from the ducts it passes over the front of the eye into the inner corner. The lachrymal secretion enters the **lachrymal duct** and is discharged into the **nasal chamber.** When the lachrymal secretion is excessive it becomes evident as **tears.** The nerve supply to the gland is freely influenced by certain mental conditions. The movements of the eyelids in **winking** assist the action of the lachrymal secretion in **washing** and **polishing** the **cornea** of the eye.

By removal of the anterior margin of the orbit the sheep's eyeball will be better exposed. The **ocular muscles** are attached by broad tendons to the anterior portion of the outer coat of the eyeball. The red muscles appear to enclose the posterior portion of the eyeball, their **origin,** except one, being around the **entrance** of the **optic nerve** at the back of the orbit. There are **six ocular muscles, four straight** or **recti** muscles, and **two oblique.** The **many** and **varied movements** of the eyeball are produced by the action of these muscles.

COATS OF THE EYEBALL. The outermost covering is formed by the cornea, the anterior, transparent portion, and the sides and back by the opaque sclerotic. The **sclerotic** portion of the outer coat is strong, fibrous, and thick. It is **well adapted** to **protect** the more delicate parts within and **to give attachment** to the ocular muscles. The **cornea** is composed of many layers of fibres and cells, making it relatively thick and strong. The cornea, like a watch-glass in form, has become **transparent** to admit rays of light passing to the interior.

On cutting through at the **junction** of the **cornea** and

sclerotic some watery fluid escapes; this is the aqueous humour. It is lodged in a space between the cornea in front and the iris behind.

The **second coat** of the eyeball lines the sclerotic **posteriorly** as the **choroid** which is continued in **front** as the **iris.** The **iris** or the coloured portion is like a circular curtain with an opening in the centre, the **pupil** of the eye; it hangs in front of the **crystalline lens.** Both the choroid and iris have a framework of connective tissue containing much **dark pigment** and a free supply of blood vessels. The choroid in its

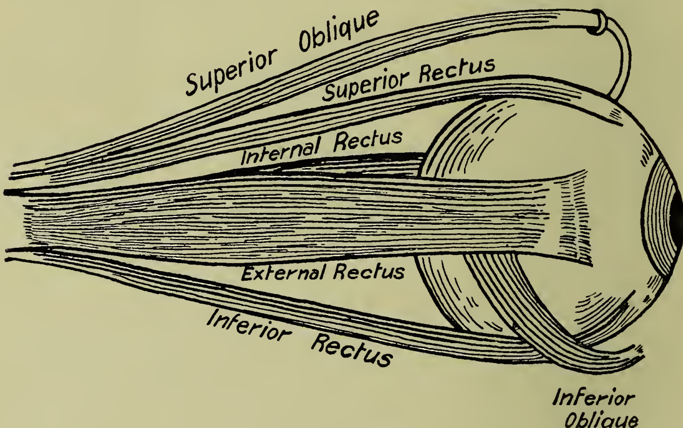

Fig. 90.—The eyeball and ocular muscles.

front portion is thickened and folded, the folds forming what are known as the **ciliary processes.**

By the **colour of the eye** is meant the colour of the iris. Grey or blue eyes owe their colour not to these coloured pigments but to the varying amount of dark-coloured pigment showing through the other structures of the iris. In dark eyes the dark pigment is more abundant and in lighter coloured eyes it is less abundant.

Around the pupil of the eye there are plain muscle fibres

supplied with nerves. Under **strong light** or on looking at a **near object**, the muscle fibres contract and narrow the pupil. On the other hand, on looking at a **distant object** or in a **dim light** the pupil widens. The form of the pupil in the eye of the cat or the sheep is unlike that in the human eye.

Crystalline Lens. After cutting away the cornea, keeping the cut part uppermost, the **iris** and its **junction** with the **choroid** is seen, and behind the iris, seen through the pupil, is the **crystalline lens.** If the iris be now cut away and a little

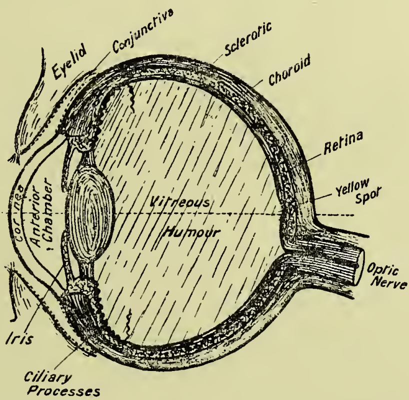

FIG. 91.—Sectional view of eyeball showing coats, position of lens, entrance of optic nerve, eyelids with conjunctiva dotted in and anterior portion of retina shown detached.

pressure at the sides of the eyeball be made, the lens will become pressed up, but does not fall out readily. The **lens** is **held** by a very **delicate, suspensory** structure at the margin, which passes back over the **ciliary folds** of the choroid. Remove the lens; it has a **crystal-like transparency, double convex** in form, and is **elastic to the touch.** The **greater convexity** is behind, where it rests against the jelly-like, **vitreous humour.** Place the lens on some print; the letters show larger, thus demonstrating the power of a biconvex lens to magnify.

The **vitreous humour** fills the interior of the eyeball. It is jelly-like in nature, clear as a crystal, and pervaded by a delicate hyaloid membrane.

The Retina. The **third coat** of the eyeball, the **retina,** is found between the vitreous humour and the choroid, and it **lines the latter** for about three-fourths of its **posterior surface.** It will now be better, with a sharp knife or razor, to cut across a fresh specimen a little behind the junction of the cornea and sclerotic coat. Turn the posterior part over and get out the vitreous humour; when this is out a **pinkish-white, gelatinous** membrane will be seen. It comes readily away from the

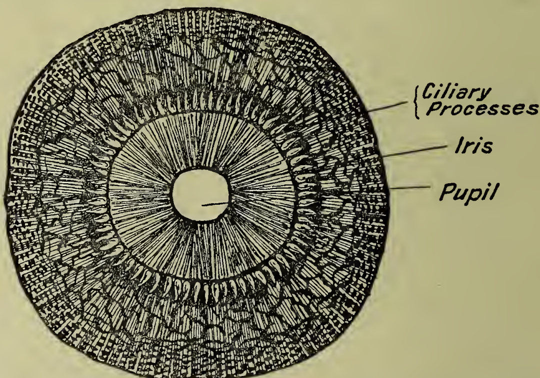

FIG. 92.—Posterior view of iris, ciliary processes of choroid coat and distribution of blood vessels.

inside of the choroid, **except** at **one point.** This point will be seen to be the entrance of the large optic nerve at the back. This is the **sensitive coat** of the eyeball, the **retina.**

A convenient way of observing the inner coat is to slice off about one-third of the anterior part of a bullock's eye with a sharp razor, leaving the vitreous humour in position in both parts. Observe through the vitreous humour the thin, opaque, pinkish-white retinal membrane with a number of branching blood vessels lying against the dark choroid coat. At the anterior portion note the **wavy edge** of the **retina** where it ends at

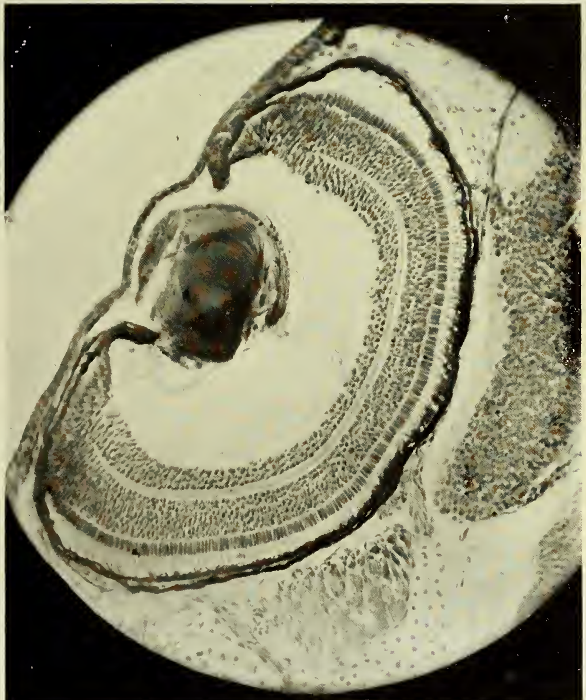

FIG. 93.—PHOTOMICROGRAPH OF SECTION THROUGH THE EYE OF A YOUNG FROG SHOWING LAYERS OF RETINAL COAT AND ENTRANCE OF OPTIC NERVE. × 200

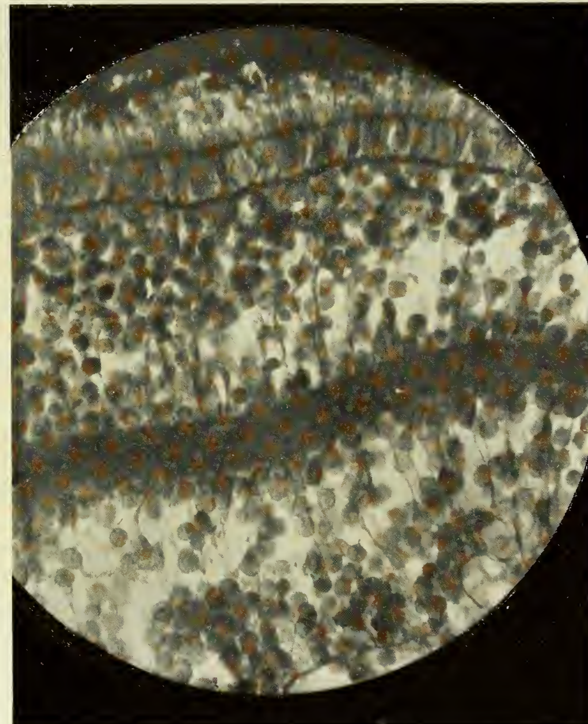

FIG. 94.—PHOTOMICROGRAPH OF A PORTION OF THE RETINA OF THE EYE OF A FROG SHOWING NUCLEAR LAYERS, GRANULAR LAYERS, RODS AND CONES AND RETINAL PIGMENT. × 450

the hinder margins of the ciliary processes. Also observe the crystalline lens in position, and looking through the lens the aperture or pupil of the iris is seen.

The **retina** of the eyeball is of remarkable structure and requires high powers of the microscope to reveal the details. When carefully fixed, hardened, and cut in very thin sections, it is shown to be made up of **layers of nerve fibres** derived from the optic nerve, **large** and **small nerve cells** with **elaborate branchings** and specially **modified epithelial cells** forming the layer known as **rods** and **cones**, and at the ends of the rods the retinal pigment cells.

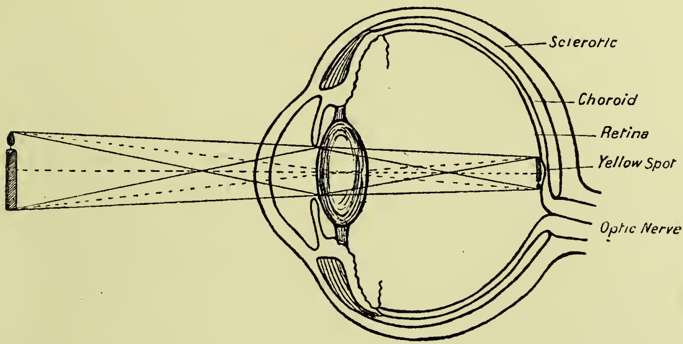

FIG. 95.—Diagram to illustrate the formation of image on the retina.

The **optic nerve,** like a white cord, is about $\frac{1}{6}$ in. in diameter. It passes from the base of the brain to enter an opening at the back of the orbit ; it continues for a short distance surrounded by the fatty tissue and optic muscles, then pierces the sclerotic and choroid, and spreads out to form that portion of the retina against the vitreous humour, whilst the portion of the retina composed of the rods and cones is near the choroid.

The Ciliary Muscle. A structure of great importance is found within the sclerotic coat at its junction with the cornea. It is a circular band of greyish appearance, composed of **radiating muscle fibres** which pass backward and become **inserted** into

the **choroid** coat. These fibres form the **ciliary muscle,** or the **muscle** of **accommodation.** The fibres of this muscle are also connected with the **suspensory ligament,** which radiates from the margin of the crystalline lens. When the ciliary muscle contracts it draws forward very slightly the choroid coat and **relaxes** the suspensory ligament, and the lens becomes more **convex** in **front.** When the muscle ceases to contract the choroid coat goes back, the **suspensory ligament** is **tightened,** and the **lens** becomes **slightly compressed,** that is, less convex. In these two conditions of the lens the eye is said to be **accommodated,** first, for seeing near objects distinctly and in the second condition for seeing distant objects distinctly. It is important to keep in view the facts already gathered regarding the crystalline lens. It is of **elastic nature ;** it is **biconvex** in form ; **it is subject to pressure** which can alter its convexity.

The Biconvex Lens. Take a biconvex lens, i.e., a lens thick in the centre and thin at the margin, such as an ordinary reading-glass, hold it before a lighted candle in a darkened room and let the image formed fall on a screen. You will observe that the rays of light from the candle passing through the lens are **bent inwards** or converged, forming the **meeting point** of the rays or the **focus.** The distance from the centre of the lens to the focus is the **focal distance** of the particular lens. Take another lens still thicker in the central part, use it in the same way. Place the lens the same distance from the candle, but in order to get the rays of light brought to a focus the screen must be placed nearer the lens. From these experiments we gather that when the convexity of the lens is increased nearer objects are focused ; when a lens of less convexity is used more distant objects come to a focus. To apply this teaching to the eye :

The **retina** is the screen and it is **fixed.** The crystalline lens is biconvex ; it can therefore converge rays of light and bring them to a focus a certain distance behind the lens, say on the retina. At the moment, say you are looking at a distant church and it is seen clearly. Now turn the eyes to look at the

face of a watch and the time is distinctly seen. To see two objects, distant and near, distinctly through the same lens **without an alteration of the convexity, or the position of the lens,** is disproved by the above simple experiment of using lenses of different thicknesses to get a focus from the candle flame.

What has taken place in the lens of the eye in looking at a distant object and then turning to a near one and seeing it distinctly, is the **increase of convexity,** the lens becoming thicker. This can be shown to be due to the contraction of the circular band of **ciliary muscle** bringing forward, slightly, the choroid coat, and **relaxing** the suspensory ligament; the tension on the front of the elastic crystalline lens is less and it becomes more convex. Again, immediately the eye is turned away from the near object to a distant one the former conditions of the choroid coat, ciliary muscle, and suspensory ligament are resumed, and the **tension** on the front of the lens is **greater** and it is **accommodated for the distant object.**

Another property of a biconvex lens may be gathered from the experiment of the lighted candle. When the lens is held in a position to secure a distinct image of the flame on the screen, it is noted that the image is upside down or **inverted.** It is hard to believe that we see objects upside down, still we cannot get behind the fact that **objects focused** with **biconvex lenses are inverted.** The crystalline lens of the eye is no exception to this teaching. Get direct proof of this by taking the lens from a fresh bullock's eye, give it support, place a small screen of tissue paper close behind the eye, and a small, illuminated object in front. Now darken the surroundings and look for the **inverted** image of the object on the screen. Or take the eye of an animal, thin down with a sharp knife or razor the back of the eyeball, that is, remove the thick sclerotic coat sufficiently to see the image of an object focused on the retina. The image is an inverted one.

The brain interprets the rays of light as they are focused in numerous small cones coming from all **points of an object,**

as **really coming from these points** and making up the **sensation** arising from an external object. The **brain takes no notice** of the **position** of the **object** on the **retina**; it simply becomes aware of the **presence of an external object** by the **stimuli** of rays of light falling on the retina. The stimuli cause **impulses** to travel by the optic nerve to the brain, and **there** produce the **sensation arising from an external object.** The retina has been always accustomed to receive stimuli by rays of light falling on its upper or lower portions, its right or left sides, and the brain has always received the consequent sensation, and external objects are **not inverted to the brain's visual sensation.**

LIGHT. We have several times referred to rays of light, and we are accustomed to represent them by so many straight or

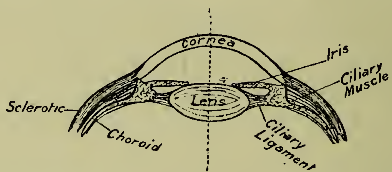

Fig. 96.—Diagram to illustrate accommodation of the eye for distant objects.

converging lines. The study of the nature of light and its behaviour must be made elsewhere. We can only note for our purpose that light is regarded as the vibration of a medium named **ether** which **occupies all space** and **pervades all matter.** This ether is set vibrating by the movement of particles of matter, and when it vibrates at an **exceedingly high rate** it **affects** the **structures connected with the optic nerve.** Impulses are set up, and as they reach the brain we become **conscious** of what we **call light.** The **retina** then is a kind of highly sensitive curtain spread out on the inside of the back of the eyeball, partly formed by a spreading out of the fibres of the optic nerve and nerve cells, and partly by **specially modified** structures known as **rods and cones.**

The retina is sensitive to rays of light focused upon its surface; but all parts of it are not **alike sensitive.** At one part, a spot in a line with the **optic axis** of the eye, i.e., a line passing through the centre of the lens on to the retina, the **retinal structures** are **specially sensitive** to **rays** of **light.** This part is named the **yellow spot.** In the **centre** of the yellow spot the retina becomes very thin, and apparently all the structures are absent except the cones. Objects focused on this part of the retina are **most distinctly seen.** The rods and cones serve as **end organs** for the nervous structures of the retina. Rays of light falling on the retina affect these first, they receive the stimuli, and the impulses resulting are carried by the fibres of the optic nerve to the brain.

The Blind Spot. At the entrance of the optic nerve through

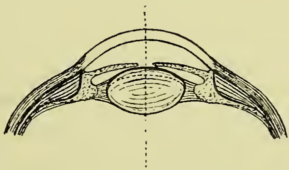

Fig. 97.—Diagram to show forward position of choroid coat and increased convexity of the crystalline lens for near objects.

the sclerotic and choroid coats at the back of the eyeball, it spreads out in thousands of the finest nerve fibres to form the **anterior portion** of the retinal structures. **Posterior** to these fibres are the rods and cones. If an image formed by rays of light from an external object fall upon the entrance of the optic nerve, **it is not seen.** Although the spot is **full** of **nerve fibres** and **nerve cells,** it can be proved to be **non-sensitive** to rays of light falling upon it. It is blind to **images of objects,** and has been named the **blind spot.** Ordinarily images do not fall on this part of the retina, because we have **formed the habit** of moving the eyes in order to secure a distinct image of the object looked at. Further, in following moving objects the images so rapidly pass over these

spots in the eyes that **we do not notice** the presence of the blind spot.

By a very familiar experiment, and by using **one eye** instead of two, the blind spot in the eye can be demonstrated. Take a card, and on it place two marks, say a cross and a dot, about 3 in. apart, the cross on the left. Now close the left eye and look with the right eye on the cross. Begin by holding the card 10 to 12 in. from the eye and gradually move the card towards the eye. Note at what distances the dot **disappears** and **reappears** in the field of vision. It can be shown that when the dot disappears it has been focused on the **entrance** of the **optic** nerve, which is non-sensitive to rays of light. When the image of the dot passes the optic nerve, and rests upon another portion of the retina, it is seen again. The nerve fibres require end organs in the form of rods and cones to be sensitive to rays of light. Just as the other senses require special endings to the nerves to become stimulated and give rise to the particular sensation.

Accessory structures to the retina. The eyeball has been compared to a photographic camera, and the comparison is followed readily. The retina is like a sensitive plate spread out in a curve, not **flat**, at the back of a **dark chamber**, provided by the pigment of the choroid coat. The **lens** is **fixed** at a certain distance from the retina, but the **convexity** of the lens can be increased or decreased, and near or distant objects can be clearly focused on the retina. This compensates for the need of lenses of different thicknesses or focal distances. If one lens be used in a camera it must be capable of being racked in and out, nearer or more distant from the object and screen. This condition is effected in the eye by **altering the convexity** of the elastic crystalline lens. Besides the **chief refracting structure** of the eye in the shape of a biconvex lens, there is the addition of a convex cornea and vitreous humour both slightly refractive in function. The photographic camera is provided with a diaphragm or stops. The diaphragm used

nowadays is the iris diaphragm. The pattern and use is well represented in the circular, muscular curtain of the eye, the iris, hanging in front of the crystalline lens. This like the camera diaphragm is acted on to regulate the amount of light that shall pass through the lens and to cut off a large number of the outside rays, and thereby getting a clearer, sharper image on the sensitive plate.

CHAPTER XXXIII

THE ORGAN OF HEARING

Like the eye, the organ of hearing contributes largely to our mental storehouse, but the eye takes in a more extensive field of knowledge than the ear. Like the eye the structure of the ear is complicated, and a detailed study cannot be undertaken at this stage. The ears are situated, as far as the more obvious parts are concerned, one on either side of the head, but strictly speaking, the **real organ of hearing** is out of sight, being lodged in the deepest portion of the temporal bone. For convenience of description **three divisions** are considered in order: the **external, middle,** and **internal ear.**

The **external ear** includes the appendage at the side of the head, and the canal leading down to the drum. The expansion at the side is the **pinna**; it has a stiffening of cartilage, irregular in shape, which is covered with skin. The lobe at the base is without cartilage, and contains fat. It is not very sensitive and stands piercing without much inconvenience. The front of the pinna shows depressions and projections, and small tufts of hair are situated partly across the entrance to the canal. The pinna does not always assume the same position; in some persons it is flat against the side of the head, and in others it stands prominently out, being apparently in a better position for catching sound waves.

Certain **small muscles** are found associated with the external ears, which in some individuals can be made to move the pinnæ. Man has largely lost this power of movement, which is so conspicuous and useful in some lower animals. The waves

of sound are collected and directed into the **external auditory canal.** This canal, about 1 in. in length, has a **curved** direction and is **slightly narrower** in the middle than at either end. This explains why such things as peas and beans which children sometimes pass into this part of the ear are difficult to extract when once they have passed the narrow portion of the canal. **The hairs found** at the entrance, to the external ear afford a protection against insects entering, and a further protection in this respect is offered by the presence of a **number**

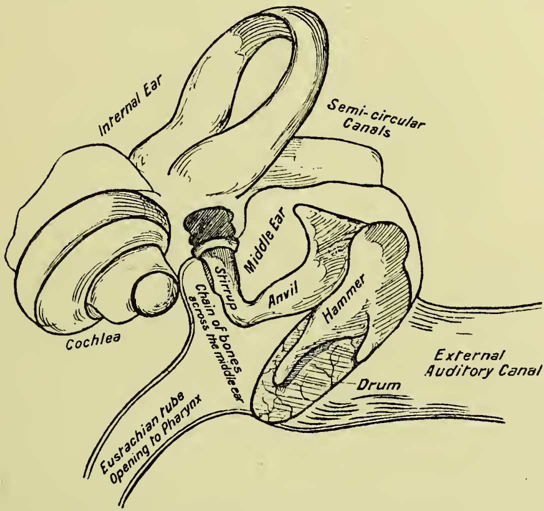

FIG. 98.—View of the external, middle and internal divisions of the ear.

of glands found in the external auditory canal which excrete a wax of a bitter taste.

At the **inner end** of the external auditory canal is the **tympanic membrane** or **drum** of the ear. This is a thin, skin-like membrane containing blood vessels, and it is **stretched obliquely across** the bottom of the canal. On the other side of the drum is the cavity known as the tympanum or middle ear.

The **middle ear** or **tympanic cavity**; think of this as an excavation in the deep portion of the temporal bone with a communication from the pharynx and a small oval opening into the internal portion of the ear. The middle ear is **lined with mucous membrane**, which is continuous with the lining of the **eustachian tube** which opens into the pharynx. The opening of this tube into the pharynx is closed except in the act of swallowing. A cold in the head often affects the mem-

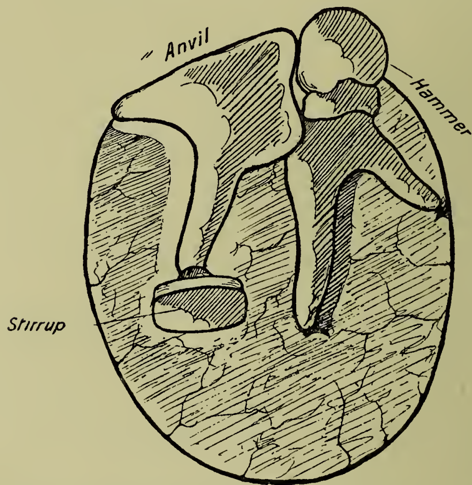

FIG. 99.—Drum of the ear from inside showing position of hammer, anvil and stirrup bones.

brane lining the eustachian tube and causes temporary deafness. The **oval window** opening into the internal ear is covered by a thin membrane against which the plate of the stirrup bone is attached. Stretched across the cavity of the middle ear from the inside of the drum to the oval window are three small bones, named **malleus, incus, stapes**, from their resemblance to the hammer, the anvil, and the stirrup. The handle of the hammer bone is attached to the inside of the

drum and moves with it, the head of the hammer articulates with the top of the anvil bone, and the longer leg of the anvil articulates with the stirrup bone, which is set at right angles to the anvil, and the foot of the stirrup fits against the oval window. These small bones have **minute muscles** to act upon them **to regulate their movements.**

The **internal ear.** Inside the oval window is the third division or internal ear. It consists of a **series of excavations** in the deepest portion of the temporal bone, having an entrance chamber or **vestibule,** three **semicircular canals,** and a **spiral shell** or **cochlea.** The semicircular canals at

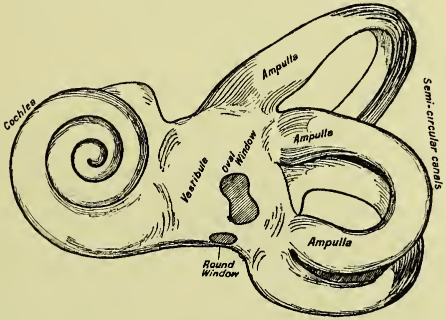

Fig. 100.—Internal ear. Bony labyrinth showing vestibule, semicircular canals and cochlea.

their openings into the vestibule enlarge and the swellings are known as **ampullæ.** At the base of the cochlea is a **round window** opening into the middle ear. This like the oval window is closed by a thin membrane.

The bony divisions of the internal ear are occupied by membranous bags drawn out, as it were, to **follow the shapes** of the bony portions. The membranous arrangement is named the **membranous labyrinth;** it contains a fluid **endolymph** and floats in a fluid named **perilymph.** The membranous portion of the labyrinth in the spiral cochlea forms a middle canal bounded by the bony walls on two sides and forming two

other canals. In this way the bony cochlea has **three divisions** named **scalæ** or **staircases.** The **middle scala** or **cochlear canal** has a membrane for its roof and a membrane for its floor. On the floor or **basilar membrane** are arranged **remarkably modified cells** forming the **organ of Corti.** A branch of the **auditory nerve** from the brain terminates among these cells of Corti. In the ampullæ of the

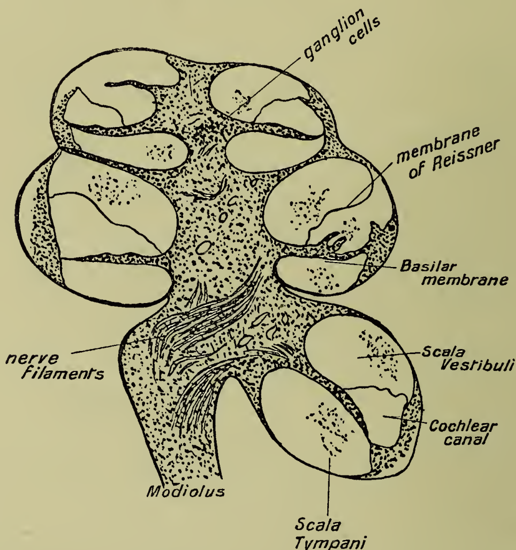

Fig. 101.—Sketch from micro-preparation of a vertical section of cochlea showing divisions into scalæ.

semicircular canals and in parts of the membranous bag contained in the vestibule, the **epithelial cells terminate** in **hair-like** projections and auditory nerves pass to these cells.

This brief description of the very complex organ of hearing, together with the several figures accompanying this chapter, will enable the student to follow the outline of the functions of the part concerned.

How we hear. Sound vibrations passing from sonorous bodies proceed as a **series of air waves** to the external ear. These are **collected** and **reflected** by the expanded pinna to the external auditory canal. The **stretched membrane** or drum at the lower end of the canal takes up the vibrations and **sets in motion** the three small bones of the middle ear. The **foot of the stirrup** bone now presses against the membrane of the oval window and the **perilymph is set in motion,** which motion affects the membranous labyrinth, and the contained **endolymph is set in motion.** As the endolymph moves over

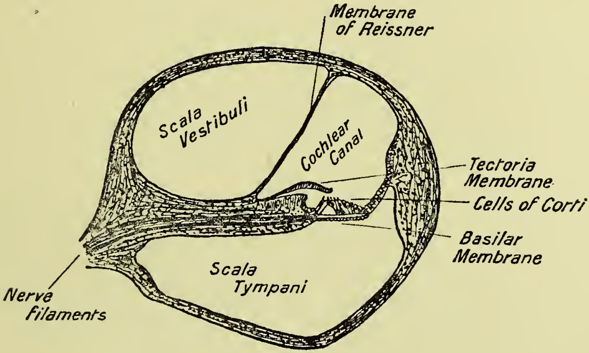

FIG. 102.—Sketch of micro-preparation to show highly magnified view of basilar membrane and cells of corti.

the modified cells of the organ of Corti, the **stimulus** causes the auditory nerve fibres to be affected, and the **impulses** are carried to the **auditory centre** of the brain and **we hear** or have the **sensation of sounds.**

Whilst the true sense of hearing is attributed to the organ of Corti contained in the cochlear canal, the other sensitive epithelial surfaces also become affected. The particular part these play cannot with certainty be stated. The semicircular canals are set at right angles one to the other. They contain endolymph, which moves over modified epithelial surfaces. As the

head moves, or the body as a whole changes its position, the fluid in the semicircular canals will move accordingly and in doing so affect the nerve endings. It is probable that through the medium of the semicircular canals we recognize our position in space. The co-ordination of the muscles and the maintenance of equilibrium in connexion with the brain is in some way influenced through this part of the internal ear.

APPENDIX

METRIC SYSTEM

The unit of length is the metre, of volume the litre, and of weight the gramme.

Multiples of these have Greek prefixes, deca (10 times), hecto (100 times), kilo (1000 times).

Fractions have the Latin prefixes, deci (one-tenth), cent (one-hundredth), milli (one-thousandth).

One cubic centimetre (c.c.) of water at the temperature of its maximum density (= 4° C.) weighs **one gramme.** For practical purposes 1 c.c. of water may be taken to weigh 1 grm. at ordinary temperatures.

A **Litre** of water (1000 c.c.) therefore weighs 1000 grm., or 1 kg.

Abbreviations:

Cubic centimetre	=	c.c.
Gramme	=	grm.
Milligram	=	mg.

EQUIVALENTS

1 metre = 39·37 in.; 1 ft. = 0·304 metre; 1 in. = 2·54 cm.

1 litre = 61·03 cub. in. = 1·76 pt.; 1 c.c. = 0·061 cub. in.

1 gramme = 15·43 gr.; 1 gr. = ·0648 grm.; 1 cub. in. = 16·386 c.c.

1 ounce (avoir.) = 28·35 grm.; (apoth.) = 31·1 grm.

1 pound (avoir.) = 453·6 grm.; (apoth.) = 373·2 grm.; 1 lb. (avoir.) = 7000 gr.

1 kilogramme = 2·2046 lb. (avoir.).

THERMOMETERS

Fahrenheit:	freezing point	32°;	boiling point	212° F.
Centigrade:	„ „	0°;	„ „	100° C.

To convert F.° into C.° and vice versa:—

$$\frac{(F.^\circ - 32^\circ) \times 5}{9} = C.^\circ \qquad \frac{C.^\circ \times 9}{5} + 32^\circ = F.^\circ$$

TABLE OF ATOMIC WEIGHTS OF THE COMMON ELEMENTS. [1909]

Element	Symbol	At. weight
Aluminium	Al	27
Antimony	Sb (Stibium)	120
Arsenic	As	75
Barium	Ba	137
Bismuth	Bi	208
Boron	B	11
Bromine	Br	79·9
Cadmium	Cd	112
Calcium	Ca	40
Carbon	C	12
Chlorine	Cl	35·5
Chromium	Cr	52
Cobalt	Co	58·9
Copper	Cu (Cuprum)	63·5
Fluorine	F	19
Gold	Au (Aurum)	197·2
Hydrogen	H	1
Iodine	I	126·9
Iron	Fe (Ferrum)	55·8
Lead	Pb (Plumbum)	207
Magnesium	Mg	24·3
Manganese	Mn	54·9
Mercury	Hg (Hydrargyrum)	200
Nickel	Ni	58·6
Nitrogen	N	14
Oxygen	O	16
Phosphorus	P	31
Platinum	Pt	195
Potassium	K (Kalium)	39
Silicon	Si	28·2
Silver	Ag (Argentum)	107·8
Sodium	Na (Natrium)	23
Sulphur	S	32
Tin	Sn (Stannum)	119
Zinc	Zn	65·3

REAGENTS

Trommer's Test (for sugars). To a solution of say, grape-sugar, add solutions of copper sulphate ($CuSO_45HO$) and potash (KOH) or soda (NaOH) = Trommer's solution. Boil this deep blue solution and a yellow or red precipitate of copper oxide (Cu_2O) is obtained.

Millon's Reagent. Dissolve 1 part of mercury in 2 parts of nitric acid (HNO_3), first at ordinary temperature, then with the aid of heat. When dissolved, add twice its volume of water and decant from any sediment. **Test for Proteids.** When substances containing proteid are boiled with this reagent, a red coloration or precipitate is produced.

Xanthoproteic Test for Proteids. To the solution containing proteid, add strong nitric acid and boil = yellow coloration. Cool, then carefully add excess of ammonia (NH_4OH) = orange coloration.

Iodine Solution (I in KI). To a one per cent solution of potassium iodide add a few crystals of iodine until a sherry-wine tint is produced.

Of the common reagents, the following strengths are conveniently used :—

Alkalies.

Ammonium hydrate (ammonia), NH_4OH, 10 per cent in water.

Sodium hydrate (caustic soda), $NaOH$, 5 per cent in water.

Potassium hydrate (caustic potash), KOH, 5 per cent in water.

Acids.

Strong Sulphuric (H_2SO_4), Nitric (HNO_3), Hydrochloric (HCl), and Acetic (CH_3COOH), or glacial acetic acid, that is, solid at ° C.

10 per cent Sulphuric = pour 1 vol. strong into 18 vols. water.

10 per cent Nitric = 1 vol. acid and 6 of water.

5 per cent Hydrochloric = 1 vol. acid and 6 of water.

Acetic acid, 6 per cent.

Ammonium oxalate .	5	per cent	in water.
Ammonium molybdate	5	„	„
Barium chloride . .	10	„	„
Copper sulphate . .	5	„	„
Ferric (iron) chloride .	5	„	„
Lead acetate . .	5	„	„
Mercuric chloride .	5	„	„
Potassium ferrocyanide	5	„	„
Sodium carbonate .	5	„	„
Silver nitrate . .	5	„	„

Lime-water = a saturated solution of calcium hydrate, $Ca(OH)_2$.

GLOSSARY

Acid (*acidus* = sour, tart); acids are compounds of hydrogen in which the hydrogen can be replaced by a metal, or can, with a basic metallic oxide, form a salt of that metal and water. Acid oxides of the same element are distinguished as -ous and -ic (as sulphurous and sulphuric), the latter containing the more oxygen. When the hydrogen is replaced by a metal, the salts formed are distinguished by the terminations -ite and -ate respectively. Acids which arc soluble in water, redden blue litmus and have a sour taste.

Albuminoids are chemical substances found in animal and vegetable tissues. They contain C, H, O, N, and S, and may be divided into (1) albumens; (2) globulins (e.g., globulin, myosin, fibrinogen); (3) derived albumens (e.g., acid and alkali albumens or albuminates as casein); (4) fibrin (fibrin and gluten); (5) coagulated proteids (coagulated albumen).

Alkali. The alkalies are strong basic compounds, capable of neutralizing acids, so that the salts formed are either completely neutral, or, if the acid is weak, give alkaline reactions. Alkalis turn reddened or neutral litmus blue, and most vegetable purples green; they have a soapy taste and feel, act on the skin, and form soaps with fats. The term alkali in commerce usually means impure caustic soda or potash.

Alkaloids are natural organic compounds containing nitrogen; they occur in many plants, are mostly crystalline, and usually have a bitter taste. They act powerfully on the animal body, and are used in medicine as quinine, morphine, etc., and are often violent poisons. The names of most end in -ine, as theine, and caffeine which occur in tea and coffee.

Amœboid. This term is applied to the movements of the colourless corpuscles or leucocytes of the blood and lymph, because of the similarity to that exhibited by the protozoan

Amœba (q.v.), one species of which is sometimes called, from its incessant changes of form, the **Proteus**.

Amyloids. This term is derived from amylum or starch, and pertains to starchy substances.

Apnœa = temporary absence or great feebleness of breath, as in the case of fainting.

Asphyxia is a condition brought about by excluding air from the lungs. In the absence of air or oxygen, the blood becomes dark in colour and poisonous to the system. If this condition is not relieved, fatal results follow.

Bacteria (microbes) belong to the vegetable kingdom and are classified under the Fungi. They are microscopic organisms which cause putrefaction and fermentation, are found throughout the alimentary canal, and are responsible for many of the complex changes occurring in carbohydrates, fats, and proteids in the body. Some organisms are also found associated with certain diseases, of which they are considered to be primarily the cause.

Bile Pigments. The principal of these are known as bilirubin and biliverdin; the former constitutes the chief colouring matter of human bile. It is probably formed from the hæmoglobin of blood. Alkaline bile with nitric acid gives a "play of colours," namely, green, blue, violet, red, and finally yellow, a test for bile pigments.

Bile Salts. The compounds making up the larger part of the solid matters of the bile are the sodium salts of glycocholic and taurocholic acids. Besides these and the biliary mucin, there are fats, soaps, etc. With cane-sugar and sulphuric acid the biliary acids give a purple colour, and this can be used as a test for their presence.

Bursæ. These are sacs or bags (*bursa* = purse) containing fluid interposed between surfaces moving over each other, as, for example, between the knee-cap (patella) and integument.

Canaliculi. See Haversian System.

Carbohydrates. The carbohydrates are composed of three elements, carbon, hydrogen, and oxygen, the two latter being in the proportion to form water, hence the derivation of the name. Carbohydrates are found both in the animal and vegetable kingdoms, very abundantly in the latter. The several members of the group differ greatly in their properties, such as power of crystallization, fermentation, power of reduction, taste, etc. They may be classified as follows:—

Glucoses, or Monosaccharides, $C_6H_{12}O_6$—
- Glucose, or grape-sugar (dextrose).
- Fructose, or fruit-sugar (lævulose).
- Galactose, Mannose, and others.

Saccharoses, or Disaccharides, $C_{12}H_{22}O_{11}$—
- Sucrose, or cane-sugar.
- Lactose, or milk-sugar.
- Maltose, or malt-sugar.

Polysaccharides, or Amyloses $(C_6H_{10}O_5)_d$—
- Starch.
- Dextrin, or British-gum.
- Glycogen, or animal-starch.
- Cellulose.
- Also several gums, etc.

Cholesterin $(C_{26}H_{43}OH)$ occurs in small quantities in the blood, bile, brain, and nerves, and also in the vegetable kingdom. It exists to a large extent in gall-stones.

Chondrin. See Gelatine.

Chyme is a semi-fluid or pulpy matter into which food is converted after it has been for some time in the stomach and mixed with the gastric secretions. It passes into the duodenum from the stomach, and yields chyle by admixture with the pancreatic juice and bile.

Crystals of Blood. These crystals are composed of oxy-hæmoglobin (q.v.), and are well seen when a drop of blood from a dog, rat, or guinea-pig is placed on a slide and covered with a drop of Canada balsam, then examined with the microscope. The crystals form in a few minutes from the blood of these animals, and are four-sided (tetrahedral) in the case of the guinea-pig, mouse giving six-sided plates, and cat or dog four-sided needles.

Dialysis. The process of dialysis depends upon the great difference of rate of diffusion of liquids through a permeable membrane. It is found that uncrystallizable bodies (colloids) diffuse at a very much slower rate than crystallizable ones (crystalloids). The apparatus used for dialysis is known as a dialyser, and may consist of a glass vessel with a septum of parchment paper, or animal membrane, stretched and securely tied over the bottom. The substance to be dialysed is poured in the dialyser on to the septum, and if it does not leak, placed in another vessel of water, when diffusion will begin immediately.

The crystalloids will pass through the membrane while the colloids remain behind. Dialysis thus affords a convenient method of separating small quantities of crystallizable substances from large quantities of colloidal material, as in separation of poisons from stomach contents, etc.

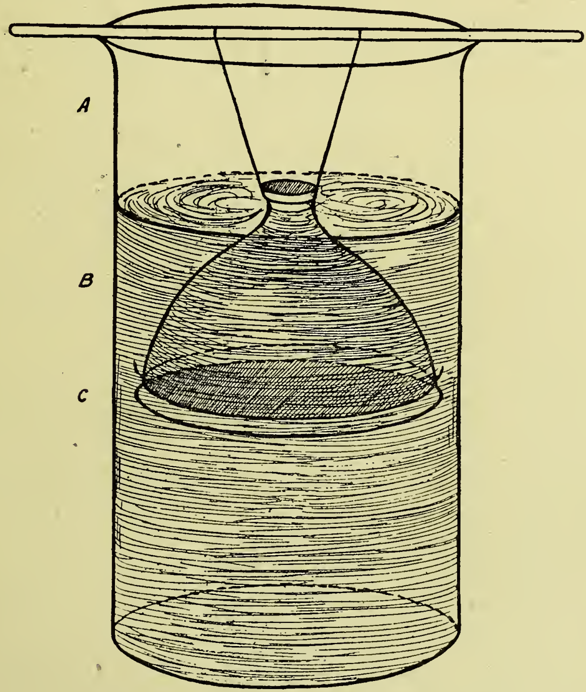

FIG. 103.—Dialyser. A. Beaker of water. B. Dialyser containing crystalloid in solution suspended in beaker from a glass rod. C. Parchment membrane tied over bottom of dialyser.

Emulsion. When a fat or oil is broken up into very small globules which do not readily run together again, or in other words, remain discrete, an emulsion is formed. A typical example of an emulsion, is milk. Certain alkaline fluids have the power of emulsifying fats; a solution of carbonate of soda (washing-soda) added to some olive or cod-liver oil will bring about this physical

change. In the body the pancreatic juice and the bile form an emulsion with fats, prior to its absorption into the lacteals.

Enzyme. See Ferment.

Ferment. This term is applied to those substances that have the power of effecting a chemical change in large quantities of substances brought in contact with it, without itself suffering change. Ferments are further distinguished as organized and unorganized. The former are represented in the vegetable organisms, yeast and bacteria, and the latter, sometimes called **enzymes**, by ptyalin, pepsin, and the pancreatic ferments. Unorganized ferments are further classified as (*a*) Amylolytic, those which change amyloses (starch, glycogen) into sugars; to this group belong ptyalin, diastase, and amylopsin. (*b*) Proteolytic, those which change proteids into peptones and proteoses, e.g., pepsin, trypsin. (*c*) Steatolytic, those splitting fats into fatty acids and glycerine, e.g., steapsin. (*d*) Inversive, converting cane-sugar-group sugars into glucose-group sugars, e.g., invertin. (*e*) Coagulative, converting soluble into insoluble proteids, e.g., rennet, fibrin-ferment and myosin-ferment.

Gelatine. When bones are treated with dilute hydrochloric acid the mineral constituents are dissolved and bone cartilage (ossein) remains. This when boiled for a considerable time with water forms gelatine, which may be obtained quite pure by precipitation with alcohol. Dry gelatine is amorphous, brittle, transparent in thin plates, almost colourless, unaltered in the air, and neutral to litmus. With cold water gelatine swells up and in hot water becomes soluble. On cooling gelatine in hot water a jelly forms varying in consistence with the amounts of gelatine and water present. This moist gelatine rapidly putrefies when exposed to the air. **Chondrin** is a variety of gelatine which is less soluble in boiling water. **Glue** is an impure gelatine obtained by treatment of bones, hoofs, horn, etc.

Gluten. When wheat-meal is placed in a muslin bag and washed with running water until all the starch is washed away, a yellowish-grey, sticky, and elastic mass is left behind. This is gluten—an albuminous or proteid substance, quickly decomposing when moist and exposed to the air. It is soluble in dilute acids, but nearly insoluble in water.

Glycogen, or animal-starch, occurs in the liver of mammals and also in molluscs, serving in some cases as reserve food

material during hibernation. It can be obtained as a white powder which dissolves in water forming an opalescent fluid. With iodine solution it gives a red coloration and does not reduce Trommer's solution, but it may be converted into glucose by boiling with dilute mineral acids. Glycogen is rapidly converted into glucose after death of an animal.

Hæmin is composed of hæmatin—the iron compound combined with a globulin in oxyhæmoglobin—and hydrochloric acid. When a drop of fresh blood or even a blood-stain is treated with glacial acetic acid on a glass slide hæmin crystals are formed. They are microscopic and appear as brown, rhombic prisms. Sometimes they are called Teichmann's crystals, and are important in proving the presence of blood.

Haversian System. In bone there are certain canals to which attention was first called by Havers. These Haversian canals protect the blood vessels constituting the nutritive system of the bones. In the spaces between the canals are the lacunæ and their canaliculi. The Haversian canals branch and traverse the length of the bone in the compact tissue, being usually smaller nearer the surface and larger nearer the marrow cavity.

Indicators. Certain substances, especially vegetable substances, are very sensitive to the action of acid and alkali, and by a change of colour thus resulting, they serve to indicate when one or the other is in excess. **Litmus**, a product of the lichen-plant, forms salts with a blue colour with alkali; these are decomposed by acids and the colouring matter is red. Thus, litmus acts as an indicator for acid and alkali, turning red with acid and blue with alkali. Paper steeped in litmus solution and dried is known as litmus paper, of which there are three kinds, blue, red, and neutral. Several other indicators exist.

Lactic Acid. This acid is contained in sour milk, and is formed in milk by fermenting milk-sugar under the influence of an organized ferment. It occurs also in the stomach and intestines, and a similar compound or isomer, called sarco- or para-lactic acid, occurs as a product of waste or animal tissues and is found especially after violent exertion.

Microscope, the use of, in the examination of minute structures. The materials are prepared, that is, fixed, hardened, and stained, and cut into very thin sections and mounted for examination. The light is reflected through the object to be examined.

The objective or power of the microscope, together with the ocular or eyepiece, magnifies the object and determines the number of magnifications, which are expressed as diameters, e.g., × 100 or × 200, etc. The staining differentiates or marks off the structures present.

Osmosis. If a solution be surrounded by an envelope or bag which allows water to pass through it, but not the dissolved substance, and the bag, with the solution in it, be placed in water, the water will pass through the bag into the solution from outside. This action is known as Osmosis. Many animal and vegetable membranes and cells possess this property of semi-permeability. Osmosis has been, however, accurately and carefully studied with artificial semi-permeable membranes, such as sausage-skin, parchment, etc. The passage of the water can be stopped by applying pressure to the solution. The pressure, which is in equilibrium with the force of the penetrating water, is named the osmotic pressure. The osmotic pressure increases with the concentration and the temperature of the solution.

Oxidation. This term is applied when substances are subjected to the transfer of oxygen, as by oxidizing agents. Similarly, **reducing agents** are those which take away oxygen and effect reduction. The diffusion of oxygen gas contained in air in the lungs, resulting in the formation of an oxidizing agent, oxyhæmoglobin, and the subsequent oxidation of tissue substances by the transfer of oxygen, constitutes a good example of oxidation in the animal body.

Reagents. Materials used for testing for other substances are classified as Reagents. Thus hydrochloric acid is a reagent which is used in testing for carbonates, silver salts, etc. It will also be often found that where solution A is a test for solution B, the latter will also serve as a reagent in testing for the former. Thus silver nitrate solution is used as a test for chlorine, hydrochloric acid, and salts.

Saponification. When fats or oils are acted upon by an alkali, soap is formed, and saponification of the fat or oil is said to have taken place. Fats may be considered as an acid, e.g., stearic, palmitic, oleic, combined with glycerine. The alkali or base on saponification unites with the acid forming soap, which corresponds therefore to a salt, setting free the glycerine.

EXAMINATION QUESTIONS

SKELETON, MUSCLE, TENDON, ETC.

Give a general account of the nature and use of (*a*) muscle and (*b*) tendon. Make a rough drawing of the position occupied by the fingers when these are respectively flexed, extended, abducted, and adducted.

Describe the general character and position of the pelvis. What are the more important organs which lie within its cavity?

What is the pelvis? What parts enter into its construction, and how is it articulated with other bones?

Give a brief description of the situation, general form, and chief functions of the following structures: (*a*) the larynx, (*b*) the radius, (*c*) the urinary bladder.

What groups of bones are present in the palms of the hands and in the digits? Explain how it is possible for the hand to turn round, and for the thumb to meet each of the finger-tips.

What bones are concerned in forming the following joints: (1) the head on the spine; (2) the elbow; (3) the hip? State what movements can be carried out in each case.

Sketch the humerus and the femur, showing their articulation with shoulder and pelvis respectively.

Make a careful drawing of a vertebra, indicating the various parts. State as far as you can the use of each part.

Give an account of the changes which occur in a muscle during contraction.

Describe briefly the three kinds of muscular tissue found in the body and say where each occurs.

BLOOD

What happens when shed blood is received into two bowls, one of which is kept still whilst the other is stirred with a glass rod?

Give a short account of the corpuscles which are seen when a drop of blood is examined under the microscope.

Describe, with the aid of appropriate drawings, the form and general structure of the corpuscles of the blood. What is their chief function ?

What gives the blood its red colour ? Explain the importance of the colouring material. Does the colour ever change, and, if so, under what circumstances ?

State the general composition of the blood. What is lymph, and how does it differ from blood ?

What are the constituents of human blood ? What is meant by "coagulation of blood" ?

In what respect does arterial differ from venous blood ? Where is the change from one to another brought about ?

HEART AND BLOOD VESSELS

Describe by means of appropriate diagrams the chambers of the mammalian heart.

Make a diagram to show the course of the blood flow through the mammalian heart. What are the chief structural differences between the right and left side of this organ ?

What is a capillary system, and how is it connected with the larger blood vessels ? What is to be remarked about the walls of the capillaries, and the flow of blood through them ?

Describe, by means of drawings, the structures displayed when the mammalian heart is cut across the ventricles. What substances compose the walls of the ventricles ?

Draw a diagram representing the general distribution of the vessels through which the blood circulates. Describe the general structure of the finest branches of this circulatory system.

Describe the general character, position, and use of the various valves of the heart, illustrating your answer by drawings.

Explain what is meant by "circulation of the blood". What evidence is there that the blood circulates, and in the manner usually described ?

Describe by the aid of sketches the structure of the mammalian heart, and indicate the origin of the great vessels.

LYMPHATICS

Give some account of the lymphatic system in man.

What is meant by a lymphatic vessel ? Give a general account of the distribution and function of the lymphatics.

RESPIRATION

In what respects does the blood change in its passage through the lungs? How would you show that the air that you breathe out differs from that which you take in?

What bony and cartilaginous structures form the framework of the thorax? In what direction do your ribs move when you take in a deep breath? Explain the cause and the effect as regards these two events. Also explain the relationship of the two.

What structures compose the framework of the thorax? What alterations in their position occur when a deep breath is taken? Explain the connexion between these alterations and the entry of extra air into the lungs.

What structures form the walls of the thorax? Explain how the form of the thoracic cavity is changed during the act of inspiration, and show how this change in form causes air to enter the lungs.

Describe the position, general structure, and functions of the diaphragm, illustrating your answer by appropriate drawings.

Explain what happens when we breathe, stating (*a*) the muscles which are used, and (*b*) how these cause air to enter and leave the chest.

Describe the mechanism of respiration in man, and state briefly the changes which air undergoes in the lungs.

What is the diaphragm? What vessels pass through it? How does it aid in the process of respiration?

Explain how air is admitted into the body and how it is expelled. What is meant by *residual* air? What part does it play in respiration?

FOOD AND NUTRITION

What food-stuffs are contained in egg and in meat respectively? What changes are produced in these (*a*) by boiling and (*b*) by digestion in the alimentary canal?

Mention the chief forms in which the chemical elements Carbon, Hydrogen, and Oxygen enter and leave the body.

State the chief forms in which the chemical elements Nitrogen and Carbon enter and leave the body? What do you consider to be the purpose of the changes which occur within the body in connexion with the substances containing Carbon? Give the reasons for your opinion on this point.

What chemical elements are present in albumen, gelatine, starch, fat, and sugar? Give an example of the occurrence of each of these in familiar articles of food. What happens if you heat albumen and sugar respectively so as to char them?

What does milk look like under the microscope? What substances give milk its importance as food, and what chemical elements do these substances contain?

What alterations are produced in bread when it is eaten, and by what means are these brought about?

ALIMENTARY CANAL

Describe the position, form, and general structure of the stomach, and its relation to other parts of the alimentary canal. What changes in the food take place in this organ?

What do you know as to the position, shape, general structure, and functions of the stomach? Illustrate your answer by an appropriate diagram, showing the relation of the stomach to other organs in the neighbourhood.

What is bile? Where is it formed, and what becomes of it?

Describe the general structure, position, and chief functions of (*a*) the parotid glands, (*b*) the pancreas, (*c*) the liver.

Describe with the aid of an illustrative drawing the arrangement of the various parts of the intestinal portion of the alimentary canal. What is the nature of the digestive processes which are carried out in the intestine?

Give the position, form, and general structure of the liver. Name three functions of this organ.

State the position, form, and function of the gall-bladder.

Give an account of the action of saliva on food.

What is saliva? Where is it formed, and what are its properties? On what does its secretion depend?

Describe the structure of one of the villi of the small intestine.

What is the general nature of the tissues which compose the walls of the alimentary canal?

Describe the structure of a lobule of the liver. How is the liver supplied with blood?

What is glycogen? Where does it occur in greatest quantity in the body? Give an account of its formation and fate.

ORGANS OF EXCRETION

How is the temperature of the body regulated ?

By what organs is watery vapour given off from the body ? Under what conditions is the amount increased or diminished ? How is the escape of watery vapour regulated ?

What is urea ? Give some account of the method of excretion from the system.

What influence has external heat and cold in maintaining the normal temperature of the body ?

What is meant by "oxidation" in the body ? Name the products resulting from oxidation.

Describe the structure of the skin. What are the functions of the skin ?

What functions in common have the lungs, skin, and kidneys ? Compare the products of these functions.

NERVOUS SYSTEM

Where is the spinal cord situated ? Describe its general form, and give an account of its physiological purpose.

By what nervous structures are motor and sensory structures brought into connexion with the spinal cord ? Is it possible for the muscles to move after the cord has been severed, and, if so, under what circumstances ?

Describe the situation and general form of the spinal cord. What does it look like when it is cut across ? How is the cord connected with the spinal nerves ?

What nervous structures are concerned in reflex actions ? Give two examples of such actions.

Enumerate the different kinds of sensation. What do you consider to be the fundamental distinction between the sensory and motor nerves of such a structure as a limb ?

How are the nerves of the body connected with the spinal cord ? What are the functions of nerves ?

What are vaso-motor nerves ? What part do they play in the circulation of the blood ?

What is the sympathetic nervous system ? Give a general account of the arrangements it presents.

What do you understand by "reflex action" in the spinal cord ?

Under what conditions are the movements of heart and lungs carried on during sleep ?

THE SENSES

Describe briefly how the waves of sound are conveyed to the parts which contain the nerves of hearing from a ticking watch held up close to the ear.

Make a rough drawing to show the means by which air pulsations can reach the auditory nerves and cause the sensation of hearing.

State the situation, general structure, and physiological purpose of the retina. Explain the meaning of the "blind spot". How can its existence be demonstrated in the living subject?

Make a drawing to show the general position of the various structures contained in the eyeball. What is the "blind spot," and why is it blind?

Explain by means of appropriate drawings the means by which the sound waves are conveyed from the external ear to the internal ear.

Describe by aid of figures the general structure of the human eye. What do you understand by accommodation?

What do you understand by the sense of touch? Give some account of the structures concerned.

What is the structure of the nose? In order to appreciate odours, it is necessary to inhale the air strongly through the nose. Why is this?

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